Northeastern
UNIVERSITY

Graduate School of Engineering

Student Guide and Catalog 2002-2003

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Mechanical Engineering (MS, PhD)
Operations Research (MS)
Telecommunication Systems Management (MS)

Graduate School of Engineering

Student Guide and Catalog 2002-2003

Northeastern University

Boston Massachusetts

Graduate School of Engineering

This Student Guide and Catalog of the Graduate School of Engineering (GSE) at Northeastern University has been developed for the convenience of our graduate students to help plan their program of study.

The Graduate School of Engineering is located in Room 130 of the Snell Engineering Center on the Boston Campus. During the fall, winter and spring quarters, it is staffed from 8:30 AM to 4:30 PM, Monday through Friday. There are office hours in the evenings during the academic year from 5:00 PM to 8:00PM on Mondays in Boston, and at the suburban campus in Burlington on Thursdays, from 5:00 PM to 8:00 PM. During the summer, the Graduate School office is staffed from 8:00 AM to 5:00 PM, Monday through Friday. All administrative matters should be referred to the Graduate School office.

Graduate School of Engineering Staff

Dr. Yaman Yener	Director
Stephen L. Gibson	Associate Director
Mikalah E. Carlson	Administrative Coordinator for Admissions
Brian K. McGuire	Administrative Coordinator for Student Services
Emily L. O'Brien	Administrative Coordinator for the Information Systems Program and Research Management
Marlys D. Vaughan	Administrative Coordinator for Administration

You may reach the Graduate School of Engineering by phone, 617.373.2711, fax: 617.373.2501, email, **grad-eng@coe.neu.edu**, or view our web site, **www.coe.neu.edu/grad_school**.

Dr. Yaman Yener
Associate Dean of Engineering
for Research and Graduate Studies

Semester Conversion Information

Northeastern University is converting its academic calendar from the current quarter system to a semester-based calendar to enhance students' education. Beginning in fall 2003, the academic calendar for graduate students in all the colleges except the School of Law and University College will consist of 15-week semesters in the fall and spring and two 7 ½-week sessions in the summer. The fall semester will run from early September to mid-December; spring semester will run from early January to late April; and summer sessions will run from early May to mid-June and early July to mid-August. The graduation timetable will remain unchanged for students who begin in the quarter system and finish under the semester calendar. For more information, please view the semester conversion Web site at **www.semesterinfo.neu.edu**.

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The University

The city of Boston has played a pioneering role in American education. Today it has one of the largest and most diverse student populations in the country. Located at the center of Boston's thriving educational and cultural life, Northeastern University is dedicated to excellence in research and scholarship and is committed to responding to the educational needs of individuals and the community. Since its beginning Northeastern has pioneered a wide range of educational programs and services for students of all ages.

Northeastern University's roots lie in the Evening Institute for Young Men founded in Boston in 1898. Classes in law were offered at a reasonable cost during the evening for those who worked during the day. The first evening law school in Boston quickly expanded to include other disciplines and added an innovative daytime program that alternated classroom study with work experience. By the time Northeastern was incorporated as a university in 1922, the school had committed itself to "cooperative education by day, adult education in the evening."

More than a century after its founding, Northeastern is a comprehensive university with seven colleges and five suburban campuses. A private nonsectarian institution of higher learning chartered and authorized to grant degrees by the Commonwealth of Massachusetts, the University is governed by a Board of Trustees elected by and from the Northeastern University Corporation, which comprises approximately 200 distinguished academic and professional leaders from around the country.

Northeastern University has developed a reputation as a world leader in cooperative education. The Cooperative Plan of Education, initiated by the College of Engineering in 1909 and subsequently adopted by the other colleges of the University, enables students to alternate periods of paid professional work and study. This educational method offers students an opportunity to gain valuable practical experience as an integral part of their education. Begun at the full-time undergraduate level, the cooperative education philosophy has been extended to the graduate level in engineering, business administration, law, professional accounting, and criminal justice.

The University's graduate programs in Arts and Sciences, Bouvé College of Health Sciences, Business Administration, Professional Accounting, Computer Science, Criminal Justice, Engineering, Law, and University College offer programs leading to master's and doctoral degrees and Graduate Certificates in a wide array of liberal arts and professional courses of study. In the field of adult education, the University offers full- and part-time graduate degree programs that are specifically designed to meet the needs and interests of adults who wish to further their education and meet their professional and career aspirations.

RESEARCH AT NORTHEASTERN UNIVERSITY

Research and scholarship are integral parts of Northeastern University's commitment to the intellectual growth and academic achievement of its students. Research activities span almost every academic field and include laboratory projects, theoretical studies, and technological applications.

Funding for research comes from federal and state government agencies, foundations, corporations, and the University itself. In recent years such industrial firms as Beckman, Analog Devices, EMC Corporation, Ford Motor Company, General Electric, and Lockheed have supported Northeastern's research programs. Currently, external grants and contracts exceed $40 million annually.

Northeastern's faculty numbers among its ranks some of the most distinguished scholars in their fields, and many have received such prestigious awards as Sloan Scholarships, Guggenheim Fellowships, National Institutes of Health Research Awards, Fulbright Scholarships, and a MacArthur Foundation grant. Faculty members lecture the world over, serve as consultants to industry and government agencies, are members of a variety of national and international committees, and are quoted frequently in the regional and national press on a wide range of subjects.

With the completion in the fall of 1996 of the $30 million, four-story Egan Research Center, Northeastern now has the resources that benefit the high level of scientific research conducted here. It has increased by 50 percent the on-campus space allocated for state-of-the-art research. It has enabled researchers in engineering, physics, chemistry, and computer science to work together in the same and adjacent laboratory modules. With the construction of the Egan Research Center, Northeastern University possesses one of the finest research facilities in New England.

Included in the center are the following College of Engineering research laboratories:

- Computational Electromagnetics
- Computer Engineering
- Communications and Digital Signal Processing
- Mechanical Behavior of Materials
- Mechanical Engineering Metallurgy
- Microfabrication
- Microwave Materials
- Optical Science
- Plasma Science and Microelectronics
- Radar and Microwave Systems
- Manufacturing and Robotics
- Robotics and Vision Systems
- Advanced Microgravity Materials Processing

Research Centers and Institutes

Northeastern University operates a number of institutes and research centers to foster research efforts in areas that cross disciplinary boundaries. Some key units are

- Advanced Scientific Computation Center
- Barnett Institute of Chemical and Biological Analysis
- Center for Advanced Microgravity Materials Processing (CAMMP)
- Center for Communications and Digital Signal Processing (CDSP)
- Center for the Enhancement of Science and Mathematics Education
- Center for Subsurface Sensing and Imaging Systems (CenSSIS)
- Center for Interdisciplinary Research on Complex Systems
- Center for Technology Management and Entrepreneurship
- Institute on Race and Justice
- Marine Science Center
- Microfabrication Laboratory
- Nano Manufacturing Research Institute
- The Institute for Molecular Biotechnology

Graduate School of Engineering

GENERAL INFORMATION

The Graduate School of Engineering offers degree programs designed to help students prepare themselves for technical positions in industrial organizations, government laboratories, research laboratories, and educational institutions. In addition to extensive day graduate programs, the Graduate School of Engineering offers Master of Science and Doctoral degree programs on a part-time basis in the evening. An interdisciplinary Doctor of Philosophy degree is also available for graduate students whose interests overlap two or more departments.

Northeastern University awards credit on a quarter-hour basis, with one quarter-hour credit roughly equivalent to three-fourths of a semester hour. The Master of Science degree requires a minimum of forty to forty-eight quarter hour credits, depending on the specific program selected. In some cases, depending upon academic background, prerequisite courses are required. Part-time students who normally carry four quarter hours each term can generally complete their programs in three and a half to four years, while full-time students, who may take twelve to sixteen quarter hours each term, may earn their degrees in as little as one year. However, full-time students receiving some form of assistantship or who are enrolled in the co-op plan or the Master of Science in Information Systems program must usually devote two years to completing their academic requirements.

The Master of Science degree with specification is granted to students who have earned a baccalaureate degree in the same engineering discipline as their graduate program. However, students who are admitted to the Computer Systems Engineering, Engineering Management, Information Systems, and Operations Research programs may be exempted from this general policy and may earn the specified degree regardless of their undergraduate training. Students holding undergraduate degrees in disciplines that do not correspond to their graduate program or that have been conferred by colleges outside the United States are usually awarded the Master of Science degree without specification upon completion of their program requirements.

SPECIAL PROGRAMS IN ENGINEERING

Women in Information Systems

The Women in Information Systems (WIS) program complements the MSIS degree program. It is designed for women with technical as well as non-technical backgrounds who seek the opportunity for a career move into the information technology field. The WIS program provides support as needed for women in the MSIS program: career seminars, job placement assistance, study groups, and informal networking opportunities.

The program's goal is to provide a complete career transition in a short time frame by building new technical skills on the knowledge and professional experience base that students have previously acquired. Most career change women start the program in the fall on a full- or part-time basis. After approximately nine months, students are offered help in locating jobs where they will be expected to work forty hours a week earning industry-competitive, entry-level salaries while completing their Master of Science degree on a part-time basis. Students may also elect to complete all MSIS degree requirements on a full-time basis.

Some of the jobs WIS women have taken upon graduating from the program include consultant, database administrator, software engineer, business analyst, and web programmer/developer. The Women in Information Systems program has enabled many women to successfully transform their career opportunities and to pursue a lucrative and satisfying career path.

Interdisciplinary Doctor of Philosophy

The Graduate School of Engineering offers the opportunity for an interdisciplinary doctoral program involving substantial work in two or more programs. A written proposal describing the areas of proposed study and research should be submitted with the student's application. Interdisciplinary study requires favorable recommendation by the sponsoring doctoral degree-granting department and approval by authorized representatives of the graduate committees of the departments appropriate to the disciplines covered by the student's proposal. The sponsoring department is the registration base of the student.

Formation of Interdisciplinary Committee

A student who has been accepted for interdisciplinary study must obtain the consent of an adviser who will direct his or her doctoral thesis. This adviser, who may or may not be a member of the registration department, will be chairman of the interdisciplinary committee for this student. A second member will be appointed from the registration department by its chairperson. These two members will obtain one or more additional members or request the director of the graduate school to do so. At least two programs must be represented on the committee, and a majority of the committee must come from doctoral degree-granting departments. The chairman of the registration department will notify the director of the graduate school of the membership of the committee as soon as arrangements are complete.

Duties of Interdisciplinary Committee

A member of the interdisciplinary committee who is also a member of the registration department will serve as the registration officer to approve the course registration for the student. A copy of the approved course registration must also be filed with the other committee members and with the graduate committee of the registration department.

The interdisciplinary committee will be responsible for overseeing the completion of all requirements. This committee must also certify to the registration department the completion of the requirements for the award of the doctoral degree.

The interdisciplinary committee must assure that the students program represents standards comparable to those of the registration department and that the program is not so broad that it has inadequate depth in any area.

The student's program may be reviewed at any time by the director of the graduate school to determine whether objectives of the program are being met.

Graduate Cooperative Education

Full-time Master's degree students in engineering may be eligible to participate in the Cooperative Plan of Education. The number of offerings available to domestic students is limited and there may be further restrictions on international student placements. Students may follow either an alternating or a parallel schedule according to availability.

To become eligible for the graduate co-op program, students must submit a completed application, resume, and a statement about what they hope to accomplish on co-op to the College of Engineering Graduate School Office, 130 Snell Engineering Center, before the end of their first quarter of study. Other eligibility requirements include: master's degree candidate; full-time enrollment; regular degree status; and a grade point average of at least a B (3.000). Additionally, students who have completed more than twenty-four hours of study are not eligible to participate in co-op unless they have made prior arrangements and there is an approved academic plan and approval from a Cooperative Education Faculty Coordinator on file in the Graduate School of Engineering Office. Students who hold a stipended assistantship, NUTA, or any similar type of award are not allowed to participate in the quarter(s) during which the award is in effect.

The alternating schedule is sequenced to include full-time co-op employment for three- or six-month periods inter-spaced with periods of classroom study on a full-time academic schedule of a minimum of eight quarter hours each quarter. The parallel schedule allows the graduate student to work simultaneously, for approximately twenty hours per week, while carrying a minimum academic load of four quarter hours per quarter. Co-op periods are limited to six months, and may not exceed twelve months over the course of the program. Under either co-op plan students must be registered for courses during their last quarter of study and are not allowed to hold a co-op position during this time.

GRADUATE DEGREE PROGRAMS IN ENGINEERING

Master of Science in Chemical Engineering
- General Program

Master of Science in Civil Engineering
- Construction Management
- Environmental Engineering
- Geotechnical/Geoenvironmental Engineering
- Structures
- Transportation Engineering

Master of Science in Computer Systems Engineering
- CAD/CAM
- Engineering Software Design

Master of Science in Electrical Engineering
- Communications and Signal Processing
- Computer Engineering
- Control Systems and Signal Processing
- Electromagnetics, Plasma and Optics
- Electronic Circuits and Semiconductor Devices
- Power Systems

Master of Science in Engineering Management
- Computer and Information Systems
- General Program
- Manufacturing Systems
- Quality Control and Reliability Analysis

Master of Science in Industrial Engineering
- Computer and Information Systems
- General Program
- Manufacturing Systems
- Quality Control and Reliability Analysis

Master of Science in Information Systems
- General Program

Master of Science in Mechanical Engineering
- Materials Science and Engineering
- Mechanics and Design
- Thermofluids Engineering

Master of Science in Operations Research
- General Program

Master of Science in Telecommunication Systems Management
- Telecom Networking
- Telecom System Development
- Telecom Business Mangement

Doctor of Philosophy
- Chemical Engineering
- Civil Engineering
- Computer Engineering
- Electrical Engineering
- Industrial Engineering
- Interdisciplinary
- Mechanical Engineering

Financial Information

TUITION AND FEES

The tuition rate for students enrolled in the Graduate School of Engineering for the 2002-2003 academic year is $575 per quarter hour of credit. Doctoral candidates making active use of University resources are charged an additional $600 per quarter residency for three quarters. (A continuation fee, equivalent to the tuition cost for one-half of one quarter hour of credit for Master of Science degrees and one quarter hour of credit for doctorates, is charged to students who have completed their course requirements but not their thesis requirements.)

Full payment of tuition and other related charges is due by the beginning of each quarter. The following are accepted methods of payment:

- Check or money order made payable to Northeastern University
- MasterCard, VISA, American Express, or Discover. Payments may be made in person or by calling our twenty-four-hour automated charge line, 617.373.2319 or 1.800.937.4067 (outside Massachusetts)
- Enrollment in the Three Payment Option (described below)

Students are responsible for the prompt payment of all bills. If a bill has not been received by the first week of the quarter, please go to the Bursar's Office where a bill will be created for you. Any discrepancies in your bill should be brought to the attention of the Bursar's Office. If there is a billing problem, pay the undisputed portion of the bill to avoid any additional late fees. For more financial-related information, please refer to the Bursar's Office Web site at **www.neu.edu/bursar**.

Three Payment Option

Northeastern University offers a three payment option plan. Information regarding this plan may be obtained at the Bursar's Office or by calling 617.373.2270, TTY: 617.373.3881. There is a nominal fee for participation in this program. Applications, along with the initial payment of one-third plus the fee are due the first Saturday of each quarter.

Tuition Reimbursement

Many companies do not pay the University directly but will reimburse their employees upon successful completion of the covered courses. In such cases, the student is responsible for full payment at the start of each quarter, or may select to use the Three Payment Option plan. Tuition may not be left unpaid pending employer reimbursement. Failure to make payments in accordance with these regulations will result in a late payment fee.

Tuition Paid for by Employers

In cases where payment is to be made directly by the employer to the University, the student must provide the Customer Service Center with a purchase order or statement from an officer of the company certifying that the company will pay the University directly. If there are stipulations associated with the payment agreement, such as a minimum grade level, the student must either pay the University directly or enroll in the Three Payment Option plan.

Refunds

Tuition refunds may be granted through the first four weeks of a quarter on the basis of the date appearing on the official withdrawal application filed with the Registrar's Office. Non-attendance does not constitute official withdrawal. Credit balances will be applied to future charges unless the Customer Service Center receives other written instructions. Refunds will be credited according to the following schedule:

Official Withdrawal Filed Within:	Percent of Tuition Refunded:
First week of the quarter	100 percent
Second week of the quarter	75 percent
Third week of the quarter	50 percent
Fourth week of the quarter	25 percent
Fifth week of the quarter	0 percent

Note: A different refund schedule may apply to courses that run less than a full quarter.

Tuition Default Policy

In cases where the student defaults on his/her tuition, the student shall be liable for the outstanding tuition and all reasonable collection costs incurred by the University, including attorney's fees.

Note: Transcripts and other academic records will not be released until all financial obligations to the University have been met.

Health Insurance Fee

All students who are matriculated in a program taking at least nine credits or more, are enrolled as full-time students, are eligible for membership in the University-sponsored health insurance plan. Students are eligible to waive the health insurance fee if they show proof of comparable coverage. Deadline dates do apply. Contact the Finance Office for specifics 617.373.2111.

Health Insurance Waiver Process

The University provides hospital insurance for all students who have matriculated, carry a course load of nine credits or more, or who are in a full-time program. This program is mandated by the Commonwealth of Massachusetts. You will be enrolled automatically in the University's plan, and $1,130.00 will be charged to your Northeastern account. Students who are covered under a comparable hospital insurance plan may waive the University-offered insurance program by filing a waiver available at the Finance Office. Forms must be filed with the Finance Office, 249 Richards Hall, Boston, Massachusetts, 02115, 617.373.2111, by the deadline dates. *Waivers submitted after the deadline will not receive a reversal of the health fee.*

For complete information regarding costs and resources please contact the Customer Service Center at 617.373.2270, or e-mail your request to **customerservice@neu.edu**. View their Web site at **www.customerservice.neu.edu/**.

FINANCIAL ASSISTANCE

Northeastern University offers graduate students a variety of means for obtaining financial assistance. In addition to various types of assistantships awarded by the individual graduate schools and administrative offices, the Graduate Student Financial Services Office administers several forms of financial aid. A limited number of fellowships are also available to minority students.

Graduate Assistantships

Of particular interest to full-time graduate students is the variety of assistantships and fellowship programs. Awards are based primarily upon the applicant's prior academic performance. Assistantship positions are typically awarded for three quarters starting in the fall and continuing through spring, although occasionally one- or two-quarter appointments are available. Students must work through final exam week. Assistantship applications may be obtained in the Graduate School of Engineering Office.

Stipended Graduate Assistantships (SGA) require twenty hours of work per week. In return, the student receives a stipend currently valued at $13,560 for the nine-month period (September to June), plus a full tuition waiver for approved course work toward their degree. The stipend portion of the SGA is viewed as taxable income by the United States government. There are three categories of SGA appointments:

Administrative Assistantships are provided by some of the administrative offices within the College of Engineering. The work performed by recipients of these positions typically involves administrative support of academic programs.

Research Assistantships are available to those students who have a strong academic background and demonstrate an interest in, and proficiency for research. These appointments are typically funded by research grants and the appointments are therefore contingent upon funding being available.

Teaching Assistantships are awarded by academic departments and are available to students with proficiency for teaching. These positions generally require the performance of teaching-related duties such as grading, conducting recitations and laboratories, and occasionally teaching undergraduate classes. Training at the English Language Center is mandatory for new teaching assistants whose native language is not English.

Northeastern University Tuition Assistantships (NUTA) require the performance of ten hours of work per week in exchange for a tuition waiver equivalent to eight credits of engineering courses each quarter. The United States government considers the tuition waiver to be taxable income as it is compensation for work performed. Typically, this type of position requires the support of faculty in their teaching or research-related activities.

Fellowship programs are available on a limited basis and are very competitive. Most fellowship programs administered by the University are open only to United States citizens or permanent residents. Fellowships have no work requirement, and may provide a tuition waiver, a stipend, or a combination of both.

Note: Assistantships and fellowships are considered a financial aid resource and may impact a student's award as determined by the Graduate Student Financial Services Office.

Financial Aid Programs

The Graduate Student Financial Services Office offers several types of assistance to graduate students, primarily in the form of loans. The preferred deadline is March 1, though students may apply later in the year. Even though students will not be awarded financial aid until they have been accepted into a degree granting program, students should apply for aid before they have been offered admission to the graduate school to expedite the process.

The Graduate Student Financial Services Office requires that a student be enrolled in a minimum of six credits (eight for engineering) to receive financial aid unless he/she is enrolled in a clinical practicum and/or doing a thesis/dissertation that is part of the program's requirements. If a student drops below half-time status, he/she may become ineligible and have to return monies. Though international students are not eligible for federal government loans such as Perkins and Stafford loans, they may be eligible for private loans such as the Teri loan.

Northeastern University requires that all applicants for financial aid (including loans) file a FAFSA in order to be eligible for consideration. The Graduate School Financial Aid application is also required. All financial aid application forms are available from the Graduate Student Financial Services Office, Northeastern University, 410 Richards Hall, Boston, Massachusetts, 02115, Phone: 617.373.5899, Fax: 617.373.5666, TTY: 617.373.5714, or online at **www.neu.edu/financial_aid/grad.htm** (PDF format). Students must apply for financial assistance annually.

Federal Perkins Loans

This program is available to full-time graduate students who show a high level of financial need and are U.S. citizens or permanent residents. Repayment and interest do not begin until nine months after the student ceases to carry at least a half-time academic load. Repayment may be extended over a ten year period with an interest rate of 5 percent per annum. No payments are required for up to three years while a borrower is serving in the Armed Forces, Peace Corps, VISTA, or while working as a full-time volunteer for a tax-exempt charitable organization performing service comparable to the service performed in Peace Corps or VISTA.

Federal Work-Study Program

This program is available to full-time graduate students who show financial need and are U.S. citizens or permanent residents. It is designed to give students an opportunity to earn as much as $8.25 per hour working in jobs on or off campus in public or private nonprofit organizations. This program is administered solely by the Graduate Student Financial Services Office and should not be confused with the University's Cooperative Education Program.

Federal Stafford Student Loan Program

The Federal Stafford Student Loan Program offers two types of student loans; subsidized and unsubsidized. The Subsidized Stafford Loan allows students who demonstrate financial need to borrow up to $10,000 annually to meet their educational expenses. The Federal Government pays the interest on a subsidized loan for students while they are enrolled on at least a half-time basis (eight credits per quarter in the engineering program) and for the first six months thereafter. The Unsubsidized Stafford Loan allows qualified students who apply for aid to borrow $10,000 annually. Financial need is not a factor. The student is responsible for all interest payments, and may elect to pay both principal and interest, interest only, or to capitalize the interest during the in-school period.

Students may borrow up to $18,500 per year in any combination of subsidized and unsubsidized loans. The combined aggregate borrowing limit for undergraduate and graduate Stafford Loans is $138,500.

To be qualified for a Stafford Loan, a student must be a U.S. Citizen or eligible non-citizen accepted for enrollment, not be in default or owe a refund of any federal monies, and have completed all required financial aid application materials. Stafford Loans will be automatically processed for the amounts listed on the Award Notification. If students wish to reject or reduce the amount of the loan, they should make the appropriate change on the Award Notification and return it to the Graduate Financial Services Office. Students do not lose their eligibility for any reductions made.

Note: Assistantships and fellowships are considered a financial aid resource and may impact a student's award.

Scholarships

Northeastern University Minority Fellowships (NUMF) are to assist a limited number of minority students accepted for full-time study in the graduate schools of the University. The awards are made to students who demonstrate superior academic achievement and are competitive within each graduate school. Stipends cover tuition and fees.

Martin Luther King, Jr. Scholarships. A limited number of full-time Martin Luther King, Jr. Scholarships are available. These scholarships pay the recipient's full tuition and student center and health fees during the course of satisfactory graduate work. Further information and applications are available at the African-American Institute, Northeastern University, 40 Leon Street, Boston, Massachusetts, 02115, 617.373.4016, **www.dac.neu.edu/jdobaai/**.

Residence Hall Staff Positions

A limited number of residence staff positions in housing facilities are available each year. Appointments carry a minimum compensation of room and board. Further information may be obtained from the Residential Life Office, Northeastern University, 6 Speare Hall, Boston, Massachusetts, 02115.

Academic Policies And Procedures

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A - Course Registration and Withdrawals

A1 - Program Approvals

The curricula of the degree programs are given under the respective department headings. Descriptions of courses are given so that students may obtain a general view of the course coverage. Preparatory courses may be required of students upon their acceptance. Not all courses are offered every year, but the courses are arranged in such a manner that students may make continuous progress toward their degrees. The Graduate School of Engineering posts a tentative schedule that lists the expected course offerings for the following academic year and the times at which they will meet. At the time of Fall Orientation, each student is expected to develop, with the assistance of the program adviser or the department's graduate officer, a complete program of study. Any subsequent changes must be approved by the adviser or the graduate officer.

A2 - Course Selections

Minimum Required Number of Courses

Full-time students in the Graduate School of Engineering must enroll on a continuous basis and maintain a minimum of twelve quarter hours of credit per quarter. However, if one of the following cases apply, then a graduate student enrolling for a minimum of eight quarter hours of credit is considered full-time:

1) If the student is an international student for whom English is a second language
2) If the student holds a Northeastern University Tuition Assistantship (NUTA)

Students who hold a Stipended Graduate Assistantship are considered full-time if enrolled for a minimum of six quarter hours of credit. Students must be registered for a full-time course load for each quarter they hold an assistantship. All graduate students who are registered in PhD or MS continuation, PhD Dissertation/Thesis, or enrolled in doctoral research are considered full-time. Part-time students may register for a maximum of six quarter hours of credit per quarter, or may petition to take more than six quarter hours of credit.

Choosing Courses

In selecting courses, full-time students should follow the schedule approved by their advisers or the department's assigned graduate officer. Part-time students should follow the outlines presented in the departmental program sections and confer with the program advisers or the department's assigned graduate officer for additional assistance as needed.

Courses other than core courses are offered according to the demand and the availability of faculty for specific areas. Students should pre-select courses whenever possible and plan to take them when offered, maintaining flexibility with alternate courses in mind. There is no guarantee that any particular course will be offered, but the Graduate School of Engineering will do everything possible to assure continuity of programs.

To register for a course offered by other Graduate Schools at Northeastern, approval from the Graduate School of Engineering must be obtained before a student can petition the other graduate program. Refer to the sub-section "Non-Graduate Engineering Courses" under Section D for further details.

Students who need assistance in course selection, course sequencing, waivers and transfer credits should contact their advisers or the department's assigned graduate officer or the Graduate School of Engineering. Additional information is provided under "Administrative Procedures."

A3 - PhD or MS Thesis Continuation

Students who have not completed their dissertation, thesis, or project after having registered for the specified number of credits must register for PhD or MS continuation each subsequent quarter during

the academic year until the thesis or project is completed. An "IP" (In Progress) will appear on the student's record for each quarter of thesis or until the thesis has been completed, at which time, the final thesis grade must be submitted by the thesis adviser.

PhD or MS continuation carries no quarter hour credit. The continuation fee is one-half the tuition cost of one quarter hour for Master of Science and the cost of one quarter hour for Doctoral degrees. Students who fail to register for continuation will be charged retroactively at the time of degree conferral for any quarters in which they did not register for continuation.

A4 - Registration Procedures

Registration is mandatory. Any student who has failed to register properly before the end of the fifth week of classes will not receive a grade at the end of the quarter, even if the course work has been completed.

PhD and MS thesis students must register for course work, dissertation, or continuation as approved by their advisers or the departmental graduate officer. After commencing studies, *registration must be continuous* unless withdrawal is allowed by the committee in charge of the degree program in which the student is enrolled.

All registration for regularly scheduled courses is conducted by telephone commencing several weeks prior to the start of each academic quarter. Instructions for telephone registration are available in the quarterly *Graduate Schools Course Offerings Booklet* published by the Registrar's Office. Late telephone registration will occur during the first week of each quarter. Course enrollment is granted on a first-come, first-served basis, and past experience indicates that many courses close early in the registration process.

For adding courses following the telephone registration period, students must obtain a *Late Course Registration Form* from the Graduate School of Engineering. Students will then be required to obtain the instructor's signature. A student wishing to drop a course after the end of telephone registration must go to the Registrar's Office or to the Burlington campus to complete an add/drop form.

A5 - Course Withdrawal / Drop Procedures

Withdrawals may be made through the ninth week of the quarter. Withdrawal forms are available at the Registrar's Office, 120 Hayden Hall, or at the Burlington campus office. Withdrawals made after the fifth week of the quarter will be recorded with a "W" on the student's transcript.

Ceasing to attend a class, or simply notifying the instructor of intent to withdraw, does not constitute an official withdrawal. Students will be charged for the course tuition and will be subject to grade of "F" should they fail to officially withdraw.

Tuition refunds are granted only on the basis of the date on which the form is filed with the Registrar's Office. Students should keep their copy of the course withdrawal form to avoid any billing error. The Bursar's Office will credit a student's account or refund tuition in accordance with the following schedule:

Official Withdrawal Filed Within:	**Percent of Tuition Refunded**
First week of quarter	100 percent
Second week of quarter	75 percent
Third week of quarter	50 percent
Fourth week of quarter	25 percent
After fourth week	0 percent

Requests for withdrawal from a course after the ninth week of the quarter may be submitted in writing to the director of the graduate school.

A6 - Common Registration Problems and Policies

Students who use telephone registration will receive confirmation of their courses by mail. Class sizes are controlled by the Registrar and set by the Director of the Graduate School of Engineering in consultation with the departments. The number of students enrolled in each class is limited to permit effective teaching at the graduate level. The University reserves the right to cancel, postpone, combine, or modify any course.

To register properly for any closed course, a student must obtain a *Closed Course Registration Form* from the Graduate School of Engineering Office. All appeals to enter a closed course must be submitted to the director of the graduate school for approval. Such permission is normally granted in cases where 1) the student has a prospective date of graduation the following June, the course is essential to his/her program, and the course cannot be taken in any of the following quarters, or 2) the student has successfully completed the first part of a sequential course. The addition of the student's name to the class list by the instructor does not constitute registration and will not entitle the student to a grade even if all the course work is completed.

Due to last minute scheduling changes, the graduate school will occasionally substitute faculty or change times for the class meetings after registration has begun. Any student who initially registered for the original course will automatically be registered for the new version should no major schedule conflicts be apparent. Otherwise, all registered students will be contacted for alternatives. Wherever possible, the graduate school will attempt to satisfy these students' first options. Once the student has received notification of a time change and when the alternative results in a schedule conflict the student is responsible for making any registration changes.

Graduate assistants must follow standard procedures for registering, dropping, and adding courses. Registration conflicts with regard to work or teaching schedules must be resolved by the graduate school, not the Registrar's Office.

Students are asked not to register for an excessive number of courses or for double sections with the intention of dropping half or more of the courses during the first week of classes. Over-registering complicates course and room scheduling, closes courses prematurely to genuinely interested students, and increases the number of changes and thus the chance of error. Students who abuse the registration process will jeopardize their program status.

Any student who is financially withdrawn prior to the start of any given quarter must clear his/her financial obligation by the end of the fifth week of the quarter in order to receive academic credit. No grades will be processed for any student who remains financially withdrawn after the fifth week of any given quarter.

As described in the "Administrative Procedures" section, course credits earned in the Graduate School of Engineering are valid for a maximum of seven years in the Master of Science degree program, and up to five years in the PhD programs (once PhD degree candidacy has been established).

All students who change their name, address, ID number, or phone number during their enrollment in the Graduate School of Engineering must inform the Registrar's Office, the Graduate School of Engineering Office, and their department separately and in writing.

A7 - Student ID Cards and Parking Permits

Full-time students can obtain a photo ID card during Fall Orientation week. Part-time students will receive their ID card (valid only in the current quarter) in the mail approximately one week before classes begin. Full-time students who lose their ID cards can get a replacement through the Husky Card Office, Customer Service Center, 254 Richards Hall. Part-time students who lose their ID cards should contact the Registrar's Office. Parking permits are obtained from the Cashier's Office, 248 Richards Hall. Parking space is available on a first-come, first-served basis.

B - Grading System

The student's performance in graduate courses will be graded according to the following numerical equivalents:

A	(4.000)	This grade is given to those students whose performance in the course has been of very high graduate caliber.
A-	(3.667)	
B+	(3.333)	
B	(3.000)	This grade is given to those students whose performance has been at a satisfactory level.
B-	(2.667)	
C+	(2.333)	
C	(2.000)	This grade is given to those students whose performance in the course is not at the level expected in graduate work.
C-	(1.667)	
F	(0)	Failure
I		Incomplete
IP		In Progress (Intended for courses such as Senior Thesis or a project that extends over several quarters)
NE		Not Enrolled: Did not attend after the date of record; will not appear on the student transcript.
S		Satisfactory (Pass/Fail basis; counts toward total degree requirements)
U		Unsatisfactory (Pass/Fail basis)
X		Incomplete (Pass/Fail basis)
L or AUD		Audit (No Credit Given; Not valid for undergraduate day programs)

Individual faculty members may choose not to use the plus and minus designations. If they elect to use the whole letters only, they must announce this to the class at the beginning of the quarter.

C - Academic Standards and Degree Requirements

C1 - Academic Classifications

Students initially entering the graduate school are classified according to their admission qualifications:

1. **Regular students** are those who meet in full all admissions criteria based on the standards established by the Committee on Graduate Study in Engineering.
2. **Provisional students or special students** are those who do not qualify for regular admission based on established standards. In order to continue in the Graduate School of Engineering and be reclassified as a regular student, these students must obtain a 3.000 grade point average in their first twelve quarter hours of course work and fulfill any specified prerequisites.
3. Those who are not pursuing a specific degree program are also classified as **special students**. These students must also satisfy the admission standards and perform work of a satisfactory level in order to continue as Special students. They are classified as non-degree students and are allowed to enroll in a maximum of twelve quarter hours of graduate credits.
4. **Transitional students** are those who are of acceptable quality but are deficient in their undergraduate preparation with respect to the program of graduate study they would like to pursue. Students with this classification are required to complete a

transitional program of study either before or concurrently with their graduate program as specified by the graduate school. Transitional students must maintain a 3.000 grade point average in their transitional program to be reclassified as regular students.

C2 - Academic Requirements

All students must satisfactorily complete an approved program of correlated work of graduate caliber and such other study as may be required by the department in which he or she is registered. Regardless of classification, any student whose record is not satisfactory may be withdrawn from the Graduate School of Engineering.

To qualify for any degree from the Graduate School of Engineering a student must have a grade point average of 3.000 or higher with no more than twelve credits below a "B-" in all courses applied toward the degree, exclusive of prerequisite courses. However, prerequisite courses are calculated into your final QPA. The Committee on Graduate Study in Engineering allows eight quarter hours of credit to be taken beyond the stated minimum degree requirements to repeat failed required courses or substitute for elective courses in order to obtain the required 3.000 average for the completion of degree requirements. Within the above limitations for extra or repeated courses, a required course for which a grade of "F" is received must be repeated with a grade of "C-" or better.

With the approval of the department and the Graduate School of Engineering, enrolled students are allowed to audit a course. While no credit will be given for an audit, audits do appear on the student's transcript. Registration changes from an audit to a graded status in a course may not be made after the first day of classes.

C3 - Changes in Requirements

The continuing development of the Graduate School of Engineering forces frequent revision of curricula and in every new bulletin some improvements are indicated. Students are expected to complete the academic requirements of the program as described in the catalog published in the year they began studies. However, they may elect to pursue the revised program requirements upon departmental approval.

C4 - Class Hours and Credits

All credits are entered as quarter hours. A quarter hour of credit is roughly equivalent to three fourths of a semester hour credit. All classes meet on a quarter basis. In the summer session, some classes meet for two, six-week periods. The academic calendar available at the Registrar's Office, in the *Graduate Schools Course Offerings* booklet, or at **www.neu.edu/top/calendars.html** should be consulted for the opening and closing dates of each academic quarter.

C5 - Code of Student Conduct

The Graduate School of Engineering will take immediate disciplinary action in all cases where a student has failed to adhere to the University rules and regulations for proper student conduct. Among others, cheating, fabrication, facilitating academic dishonesty, and plagiarism are considered violations which may result in immediate dismissal from the graduate engineering program. Students should refer to the University's *Undergraduate and Graduate Student Handbook* for additional information.

C6 - Continuity of Program

Students are expected to maintain continuous progress toward their intended degree. A student who has attained eight quarter hours of incomplete (I) grades and/or withdrawals may, at the discretion of the director of the Graduate School of Engineering, be withdrawn for failure to show continuous progress toward the degree.

C7 - Commencement Procedures

Each student who plans to graduate either in June or September must submit to the Registrar's Office a completed commencement card in the fall quarter of the academic year in which the student expects to graduate. If the deadline for filing is not met, there is no assurance that the degree will be awarded that year. The commencement card is mailed to all students registered during the fall quarter or is available in the Registrar's Office. It is the student's responsibility to make sure that degree requirements have been met (e.g. applicable petition forms filed and all grades submitted), subject to confirmation by the Graduate School of Engineering.

C8 - Incomplete Grades

The "I" grade will be changed to a letter grade when the deficiency, which led to the "I" is corrected to the satisfaction of and in the manner prescribed by the instructor in the course. The period for clearing such a grade will be restricted to one calendar year from the date of its first being recorded on the student's permanent record.

C9 - Prerequisite / Advanced Undergraduate Courses

Prerequisite courses will not be given credit toward degree requirements unless expressly stated by the individual departments. Advanced undergraduate courses are sometimes approved for graduate degree credit. A request must be made on a Graduate Engineering Petition form and submitted to the Graduate Engineering Office for approval. (See the "Administrative Procedures" section.) The maximum number of prerequisite credits allowed is determined by each academic department and is specified under the course curriculum for each concentration/degree program.

C10 - Time Limitations

Course credits earned in the program of graduate study, or accepted by transfer, are valid for a maximum of seven academic years in the Master of Science degree programs, up to five years in the Engineer Degree programs, and up to five years in the PhD programs once degree candidacy has been established. (Refer to section D8 for information regarding time limit extension.)

D - Administrative Procedures

D1 - Change in Major / Degree Program

A change in major area of concentration within the same department may be done using a petition form obtained from the Graduate Engineering Office. The completed petition, along with an unofficial transcript of your graduate work, should be presented to your adviser or the Department's assigned Graduate Officer for his/her approval. All of these materials are then submitted to the Graduate Engineering Office by the department for final approval. *Please Note: A change in degree program requires submitting a new application. This can be done by requesting, in writing, the Graduate Engineering Office to bring your file before the new department's Admission Committee for review. You should provide to the Graduate Engineering Office an unofficial graduate engineering transcript, and any other materials needed.*

D2 - Change in Status Classification

A change of status from full-time to part-time in the same program may be done by filing a completed petition with the Graduate Engineering Office. Due to immigration regulations, students on an F-1 or J-1 visa cannot request part-time status. If you are having academic difficulties, the Graduate School of Engineering will recommend a remedial course of action for you. International students on other types of visas must confirm eligibility with the International Student Office.

To change status from part-time to full-time in the same program, you must have a minimum of 12QH with at least a 3.000 grade point average. Present a completed petition and unofficial graduate engineering transcript to your adviser or the department's assigned graduate officer for

approval. All of these materials are then submitted to the Graduate School Office by the department for final approval. *Please Note: A change of major or status into a different department requires re-application. Upon receipt of the new application, the Graduate Engineering Office will bring your file before the new department's Admission Committee for review. You should provide to the Graduate Engineering Office an unofficial graduate engineering transcript, and any other materials needed.*

D3 - Course Repeat and Course Substitution

You may repeat a course, in which case the original grade remains on your transcript but is no longer calculated into your QPA. The Registrar's Office will automatically designate "Repeat" by a course when you retake the same course. However, when a two-part sequence is taken to replace the four quarter hour equivalent, a special request from the Graduate Engineering Office has to be made to the Registrar's Office. In order to have "Substitution" noted by the course on your transcript, you need to file a completed petition with an unofficial transcript and your adviser's or the Department's assigned graduate officer's approval. After the final approval by the director or his/her designee, the Graduate Engineering Office will then notify the registrar. A course substitution is the replacement of a graduate level course already taken with an equivalent graduate level course. *Please Note: There is an eight quarter hour limitation on the number of courses you may repeat or substitute. Also, when the notation of "Repeat" or "Substitute" is beside a course on your transcript, the course's grade is no longer calculated into your overall grade point average.*

D4- Course Waiver

A course waiver replaces a required course not yet taken in your degree program with an alternative course. To do this, submit a completed petition and unofficial transcript, with the reason for your request, to your adviser or the Department's assigned Graduate Officer for approval. All petitions are then filed with the Graduate Engineering Office for final approval.

D5 - Non-Graduate Engineering Courses

To request that an advanced undergraduate engineering course be applied to your graduate degree program, you will need to submit a completed petition with your adviser or the department's assigned graduate officer for approval. With your petition you must submit all the necessary documents, including an unofficial transcript of both the undergraduate course (if already taken) and graduate courses, to support your request. *Please note: You will need to provide a letter stating that the course was not used toward another degree.* After final approval by the director of the graduate school, the course and its grade will be used toward your graduate degree requirements. There is a four quarter hour limit on the number of undergraduate credit hours which may be used for the graduate degree.

In order to receive credit for graduate courses at Northeastern outside of the School of Engineering, you will need to obtain approval from the Graduate Engineering Office. Submit a completed petition, including an unofficial transcript, to your adviser or the department's assigned graduate officer for approval. Then, if approved, take your copy of the petition to the graduate school in which the desired course is offered. Usually, you will need to complete a different type of petition for that graduate school at least four weeks prior to the quarter in which the course is being offered. Your copy of the Graduate Engineering petition is verification of approval, and will designate if the non-engineering graduate course is to be applied toward your degree. Interdisciplinary degree students are not required to follow this procedure when the courses are considered part of the degree program.

D6 - Transfer Credit

The Graduate School of Engineering allows up to twelve quarter hours of credit obtained from another institution to be used toward the Master of Science degree. To be eligible for transfer credits, the course(s) must be 1) in the student's field of study, 2) at the graduate level, 3) in an accredited (or if international, a recognized) college or university, and 4) carry grades of B (3.000) or better. The

credits cannot have been used toward any other degree and must have been taken within the time limit for your degree completion. Once enrolled in the program, a student wishing to take a course from another institution for transfer credit should petition for approval prior to pursuing the course.

If you are seeking transfer credit approval, you will need to complete a petition and provide an unofficial transcript of your graduate work at Northeastern, a course catalog description and the equivalent Northeastern course. Submit all of these materials to the department graduate committee. If recommended by the department graduate committee, the material is sent to the Graduate School Office for final approval. The credits will be applied toward your degree requirements if all transfer credit criteria have been met. However, the grades do not carry over and are not included in the computation of your grade point average required for degree completion. Credits are granted as equivalent to required or elective courses in the Graduate School of Engineering. *Please note: Upon completion of course work, you must submit an official transcript to the Assistant Director of the Graduate School of Engineering for posting of transfer credit.*

D7 - Thesis / Dissertation

Instructions for the preparation of a thesis/dissertation are available from the Graduate School Office, and include proper formatting and procedures for depositing the thesis in Snell Library. The thesis topic is developed with your adviser and the final thesis is approved in accordance with the regulations of the Graduate School of Engineering outlined in the instructions.

D8 - Time Limit Extension

If you come to a point in your graduate work where it becomes evident that you cannot complete your program within the time limit (seven years for Master of Science degree, five years for PhD candidates), you will need to request approval for a time extension from the Committee on Graduate Study. This requires that you submit 1) a completed petition 2) an unofficial graduate engineering transcript, and 3) a letter from you stating the reasons for the request, to your adviser or the department's assigned graduate officer. Your letter, addressed to the Committee on Graduate Study, should also state the specific course of action you plan to take in order to complete your degree requirements, and the length of time needed for the extension.

Department of Chemical Engineering

The Department of Chemical Engineering offers the degrees of Master of Science in Chemical Engineering, Master of Science without specification, and Doctor of Philosophy. Students may pursue the Master of Science degree in Chemical Engineering on either a full- or part-time basis. The Master of Science degree without specification is pursued on a continuous full-time basis consistent with the residence requirements for the degree.

Full-time Master of Science degree students and Doctoral candidates are able to select thesis topics from a diverse range of faculty research interests. Graduate student seminars are held on a regular basis to provide an interactive forum for learning about departmental research and to exchange ideas. Most courses are offered in the late afternoon or early evening to make them readily accessible to part-time students pursuing full-time careers.

Master of Science degree students wishing to change their status from part-time to full-time must notify the Chemical Engineering Department and file a petition with the Graduate School of Engineering. Such requests are usually granted for the full-time program to begin in the fall quarter. Please refer to the regulations of the Graduate School of Engineering for information on academic administrative policies.

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of forty quarter hours of academic work is required of all students. A thesis of ten quarter hours of credit and two quarter hours of seminar are required of all continuous and cooperative full-time students to qualify for the Master of Science in Chemical Engineering, in addition to the required courses. All Master of Science degree students must attend seminars and present a seminar on their thesis work to at least three department faculty before final acceptance. The sequence of courses students take on this plan is established by their adviser. Part-time students may progress according to their abilities but must complete the degree requirements within the seven-year time limit. A minimum of forty-four quarter hours of academic course work is required of part-time students. The thesis and seminar course are not required for part-time students or unspecified Master of Science degree candidates.

A Master of Science in Chemical Engineering will be awarded to those students with a Bachelor of Science in Chemical Engineering or a closely-allied engineering field. Students with a Bachelor of Science degree in another engineering or related science field and an appropriate background of preparation may qualify for the degree of Master of Science with specification. Such students are required to complete supplementary undergraduate work, which is not included in the minimum course requirements.

Course Requirements	Thesis Option	Non-Thesis Option
Required Core Courses	16 QH	16 QH
Master of Science Thesis	10 QH	0 QH
Seminar*	2 QH	0 QH
Elective Courses**	12 QH	28 QH
Minimum Quarter Hours Required* **	**40 QH**	**44 QH**

* Seminar required for all full-time students.

** Students may complete a maximum of 10 QH (Thesis Option) or 12 QH (Non-Thesis Option) of course work outside of the Chemical Engineering Department with approval of the Chemical Engineering Department.

*** Exclusive of any preparatory courses.

Required Core Courses

			Credits
	CHE 3300	Chemical Engineering Mathematics	4
	CHE 3310	Chemical Engineering Thermodynamics	4
	CHE 3500	Transport Phenomena	4
	CHE 3671	Chemical Engineering Kinetics	4
	CHE 3691	Seminar	2
	CHE 3861	Master of Science Thesis	4
Or	CHE 3862	Master of Science Thesis	2

Elective Courses

		Credits
CHE 3320	Separation Processes	4
CHE 3330	Chemical Process Control	4
CHE 3340	Heterogeneous Catalysis	4
CHE 3350	Chemical Process Heat Transfer	4
CHE 3360	Process Safety and Risk Analysis	4
CHE 3400	Advanced Chemical Engineering Calculations	4
CHE 3410	Numerical Techniques in Chemical Engineering	4
CHE 3530	Advanced Management Techniques in the Chemical Industry	4
CHE 3560	Fluid Mechanics	4
CHE 3600	Polymer Science	4
CHE 3620	Principles of Polymerization and Polymer Processing	4
CHE 3630	Chemical Process Pollution Control	4
CHE 3670	(3701, 3702) Special Topics in Chemical Engineering	4

THE DOCTOR OF PHILOSOPHY DEGREE

The Chemical Engineering Department offers the degree of Doctor of Philosophy on a continuous full-time basis. The following sections constitute the requirements for the doctoral program. Each student admitted to the program will initially have the status of Doctoral *Student*. A student becomes a Doctoral *Candidate* upon successful completion of the *Doctoral Qualifying Examination*. After candidacy has been established, a candidate must complete a dissertation under the direction of a

dissertation adviser and a program of academic course work. To receive a PhD degree a candidate must also pass a final oral examination.

Doctoral Qualifying Examination

Successful completion of the Doctoral Qualifying Examination is the minimum requirement for consideration as doctoral degree candidate. The qualifying examination includes both written and oral components. The written component is normally given in the spring quarter. The oral component consists of a thesis proposal defense given within four months of passing the written doctoral qualifying examination. The written examination, in general, will cover the following areas: Thermodynamics, Kinetics and Reactor Design, Process Control, Unit Operations, Fluid Dynamics, Mass Transport, Heat Transfer, Process Design, and Applied Chemistry. Other topics may be included as deemed appropriate to fundamental understanding at the undergraduate level.

Course Requirements

A minimum of sixty quarter hours of academic course work beyond the bachelor of science degree in chemical engineering is required. The sixty quarter hours must include at least twenty-four quarter hours of academic course work (exclusive of thesis and seminars) taken at Northeastern University. All of the core courses for the specified masters degree must be included in the student's academic graduate course work. Seminar is required for all full-time students who choose the Thesis Option. The course requirements in addition to the minimum requirements for establishing degree candidacy will be determined by the departmental graduate committee.

Upon successful completion of the PhD qualifying examination and the majority of required course work, the student is also required to register for three consecutive quarters for CHE3880, Doctoral Thesis. Upon completion of this sequence, the student is also required to register for CHE3799, PhD Thesis Continuation in every quarter until the dissertation has been completed. Students may not register for continuation until the three quarter thesis sequence has been fulfilled.

Language Requirement

There is no foreign language requirement for the Doctor of Philosophy degree. The candidate must be proficient in technical writing and oral presentation in the English language. Appropriate course work may be required by the departmental graduate committee.

Residence Requirement

The residence requirement is satisfied by completing one academic year of full-time graduate studies during three consecutive academic quarters after successful completion (passing) of the Doctoral Qualifying Examination. Additional academic course work (exclusive of thesis and seminars) may be required and completed during this period. However, it is expected that at least two years of full-time graduate study will be required beyond the Master of Science degree.

Dissertation

After degree candidacy has been established, a candidate must complete a dissertation, which embodies the results of extended original research and includes material suitable for publication. The student can discuss PhD dissertation topic offerings with the faculty if they need a dissertation topic. After these discussions, the student shall notify the adviser, the department head, and the chairman of the departmental graduate committee in writing of his/her choice of dissertation topic and adviser. The chairman of the departmental graduate committee, after consultation with the adviser, shall appoint an appropriate *Doctoral Dissertation Committee.* This committee shall be kept informed of the progress of the dissertation and will approve the dissertation in its final form.

Final Oral Examination (Thesis Defense)

The final oral examination is taken after completion of all other requirements for the degree and is given after the dissertation has been completed and approved by the dissertation adviser. The examination is based upon a defense of the subject matter of the dissertation.

FACULTY

Professors

Sacco, Jr., Albert, PhD, Massachusetts Institute of Technology; catalysis, advanced microgravity materials processing, carbon filaments

Willey, Ronald J., PhD, University of Massachusetts, Amherst; heterogeneous catalysis

Associate Professors

Bac, Nurcan, PhD, Middle East Technical University, Ankara, Turkey; Zeolite and crystal growth in space. Membrane separation, zeolite/polymer mixed matrix membranes, advanced materials

Barabino, Gilda A., PhD, Rice University; biomedical and biochemical engineering, tissue engineering

Assistant Professors

Lee-Parsons, Carolyn W.T., PhD, Cornell University; biochemical engineering, bioreactor design and construction

Ziemer, Katherine S., PhD University of West Virginia; semiconductor material development and processing

Program Advisers

MS Specified	Professor Ronald J. Willey
MS Unspecified	Professor Nurcan Bac
PhD Program	Professor Albert Sacco, Jr.

Each course description includes information on the expected quarter in which classes are usually offered. The quarters listed are presented here for planning purposes; however, the Graduate School of Engineering cannot guarantee that all courses will be offered. Students must refer to the Graduate School of Engineering Quarterly Course Offering booklets to determine the courses that are actually offered in any given quarter.

CHE 3300 Chemical Engineering Mathematics (4QH)

Formulation and solution of problems involving advanced calculus as they arise in chemical engineering situations. Methods covered will include ordinary differential equations, series solutions, complex variables. Laplace transforms, partial differential equations, and matrix operations. Emphasis will be placed on methods for formulating the problems. It will be assumed that the student has been exposed to some of these topics in appropriate mathematics courses. *Prerequisite: BS Degree in Chemical Engineering including mathematical analysis.*

CHE 3310 Chemical Engineering Thermodynamics (4QH)

Classical thermodynamics as a method of approach to the analysis of processes of interest to chemical engineers. A study of phase equilibria involving the various states of matter; prediction and correlation of physical, chemical, and transport properties of gases and liquids; elementary concepts of quantum and statistical mechanics to interpret the empirical properties of classical thermodynamics. Fundamental principles are reviewed to the extent needed. *Prerequisite: BS Degree in Chemical Engineering.*

CHE 3320 Separation Processes (4QH)

Calculation and design methods used in processes involving mass transfer. Topics covered include vapor liquid equilibria for binary and multicomponent systems, multicomponent distillation, absorption, and extraction. Emphasis is placed on methods and techniques common to many separation processes. *Prerequisite: BS Degree in Chemical Engineering.*

CHE 3330 Chemical Process Control (4QH)

Modeling for process control, degrees of freedom analysis, linearization and state-variable format for process models, simulation of single and multivariable control systems, controller design by direct synthesis and internal model control methods, feed forward and cascade control, pairing manipulated and controlled variables in multivariable control. *Prerequisite: Admission to the Graduate School of Engineering.*

CHE 3340 Heterogeneous Catalysis (4QH)

Experimental methods required for determining the surface area and pore structure of catalyst carriers are discussed. These structural characteristics are utilized to estimate mass and heat transport rates within porous catalysts in order to determine their effectiveness with respect to chemical reaction. Mechanisms for chemical poisoning of catalysts are also analyzed. Reactions of practical interest are used to illustrate the applications of heterogeneous catalysis to modern chemical processing problems. *Prerequisite: BS Degree in Chemical Engineering.*

CHE 3350 Chemical Process Heat Transfer (4QH)

Empirical methods and calculations used to design heat transfer equipment for the chemical process industries. Review of basic heat transfer principles. Shell-and-tube calculations for liquid and/or vapor phase heat transfer. Direct contact and other special heat exchanger applications. *Prerequisite: BS Degree in Chemical Engineering.*

CHE 3360 Process Safety and Risk Analysis (4QH)

As Announced

This class is intended for anyone interested in understanding, mitigating, or eliminating the risks associated with handling chemicals. Various methods to determine exposure, radiation, and environment risk assessments will be covered. The class will also cover methods to control processes that use flammable materials or have potential runaway reactions. *Prerequisite: BS Degree in Chemical Engineering.*

CHE 3400 Advanced Chemical Engineering Calculations (4QH)

As Announced

Fundamental process principles leading to an understanding of the stoichiometric principles of chemical process plants. The study of complex material and energy balances is undertaken with the view to apply these principles to actual large chemical plant conditions. *Prerequisite: BS Degree in Chemical Engineering including differential equations.*

CHE 3410 Numerical Techniques in Chemical Engineering (4QH)

Digital computer applications to chemical engineering problems. Topics covered include location of roots of linear and nonlinear equations, numerical integration, and curve-fitting techniques with emphasis on the numerical solution of ordinary and partial differential equations and on the subject of linear algebra. *Prerequisite: BS Degree in Chemical Engineering.*

CHE 3500 Transport Phenomena (4QH)

Momentum rate conservation equations for steady-state fluid flow in two-dimensional boundary layers are presented and solved to obtain the fluid velocity profiles. These results are utilized in the consideration of heat and mass transfer phenomena at a fluid-solid interface. The development of surface renewal theory is presented and applied to the description of heat and mass transfer phenomena. *Prerequisite: BS Degree in Chemical Engineering.*

CHE 3530 Advanced Management Techniques in the Chemical Industry (4QH)

Management techniques applied to the chemical industry. Special attention to management of research organizations and to management of engineering services, such as design, computer, and related activities. *Prerequisite: Graduate standing.*

CHE 3560 Fluid Mechanics (4QH)

Discussion of statics, kinematics, and stress concepts associated with fluids. Formation of the general equations of motion with

application to laminar and turbulent flow. Topics on boundary layer theory and compressible flow are included. *Prerequisite: BS Degree in Chemical Engineering.*

CHE 3600 Polymer Science (4QH)

Basic concepts of polymers, thermodynamics of polymer solutions and measurement of molecular weight. Physical and chemical testing of polymers. Crystallinity in polymers and rheology of polymers. Physical and chemical properties of polymers. Mechanisms and conditions for polymerization of polymers including step-reaction, addition and copolymerization. Discussion of carbon-chain polymers, fibers and fiber technology. *Prerequisite: BS Degree in Chemical Engineering or Chemistry.*

CHE 3620 Principles of Polymerization and Polymer Processing (4QH)

Introduction to polymers and polymer properties. Mechanisms of polymerization including step polymerization, radical chain polymerization, emulsion polymerization, ionic-chain polymerization, chain copolymerization, and ring-opening polymerization. Stereo chemistry of polymerization and synthetic reactions of polymers. Applications to reactor design of industrially important polymers. *Prerequisite: Graduate standing in Chemical Engineering.*

CHE 3630 Chemical Process Pollution Control (4QH)

The basic fundamentals for handling environmental problems in the chemical process industries. Water quality requirements and industrial waste characteristics; wastewater treatment processes applicable to environmental engineering; biological treatment processes and equipment; comprehensive design problems involving biological and tertiary treatment; the economics of water treatment and reuse. *Prerequisite: Graduate standing in Chemical Engineering.*

CHE 3670 Special Topics in Chemical Engineering (4QH)

Topics of interest to the staff member conducting this class are presented for advanced study. A student may not take more than one Special Topics course with any one instructor. *Prerequisite: Permission of department Faculty.*

CHE 3671 Chemical Engineering Kinetics (4QH)

The theoretical foundations for the analysis of elementary chemical reaction rates. such as collision theory, particle dynamics, and transition state theory are presented. Consideration is given to the theory of mono-molecular reactions and the effect of solvent and electrostatic forces on liquid phase reaction rates. Homogeneous catalysis and selected free-energy correlations are covered. *Prerequisite: BS Degree in Chemical Engineering.*

CHE 3691 Seminar (2QH)
Any Quarter

Topics of an advanced nature are presented by staff, outside speakers, and students in the graduate program. This course must be attended every quarter by all full-time graduate students. *Prerequisite: Graduate standing in Chemical Engineering.*

CHE 3692 Seminar Continuation (0QH)
Any Quarter

Continuation of CHE 3691. *Prerequisite: CHE 3691.*

CHE 3701 Special Topics in Chemical Engineering 1 (2QH)
Any Quarter

Topics of interest to the staff member are presented for advanced study. A student may take this course and its continuation in CHE 3702 with the same instructor. *Prerequisite: Admission.*

CHE 3702 Special Topics in Chemical Engineering 2 (2QH)

Continuation of CHE 3701. *Prerequisite: CHE 3701.*

CHE 3798 Masters Continuation (0QH)
Any Quarter

CHE 3799 PhD Continuation (0QH)
Any Quarter

CHE 3861 Thesis (Master's Degree) (4QH)
Any Quarter

Analytical and/or experimental work conducted under the supervision of the department. Ten quarter hour maximum credit for thesis. Students normally register in CHE 3861 or CHE 3862. *Prerequisite: Graduate standing in Chemical Engineering.*

CHE 3862 Thesis (Master's Degree) (2QH)
Any Quarter

CHE 3880 Thesis (PhD Degree) (0QH)
Any Quarter

Theoretical and experimental work conducted under the supervision of the department. *Prerequisite: Admission to doctoral program in Chemical Engineering.*

Department of Civil and Environmental Engineering

The Department of Civil and Environmental Engineering offers graduate programs leading to the degrees of Master of Science in Civil Engineering, Master of Science (without specification) and Doctor of Philosophy in Civil Engineering. At the master's level, there are degree programs in construction management, environmental engineering, geotechnical/geoenvironmental engineering, structural engineering, and transportation engineering. The PhD level program is flexible and can be adapted to any subject area in Civil Engineering.

The Master of Science degree requirements may be completed on a full- or part-time basis. In either case, the student must meet with their faculty adviser during the first quarter of study to arrange for an appropriate sequence of courses that will satisfy the degree requirements. The PhD degree program must be completed on a basis consistent with the residence requirements for the degree.

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of forty quarter hours of credit, exclusive of any preparatory courses, with a minimum overall grade point average of 3.000 is required in all programs. Students who receive financial support from the University in the form of research assistantships, teaching assistantships, or tuition assistance are required to complete either a four quarter hour Master of Science Report or an eight quarter hour Master of Science Thesis, which counts toward the forty quarter hour requirement.

Students holding a Bachelor of Science in Civil Engineering degree who successfully complete program requirements will receive a Master of Science in Civil Engineering degree. An unspecified Master of Science degree will be awarded to those students who do not hold a Bachelor of Science in Civil Engineering.

Please refer to the regulations of the Graduate School of Engineering for information on academic and administrative policies.

Construction Management

The Construction Management program consists of required core courses primarily from the Department of Civil and Environmental Engineering, complemented by electives from Civil and Environmental Engineering; Mechanical, Industrial and Manufacturing Engineering; or from the Graduate School of Business Administration. Based on proven proficiency in given areas, certain required core courses may be waived and replaced with alternative courses. In addition to the required core, students choose one or a combination of the following program options: Construction

and Engineering, Business Management, and/or Systems Engineering. Each student is required to prepare a program of study, which must be reviewed and approved by a faculty adviser during initial registration. Graduate courses not currently listed as technical electives may also be approved as such by the student's adviser, provided they are consistent with the student's program.

Course Requirements	With Thesis	With Report	Course work Only *
Required Core Courses	19 QH	19 QH	19 QH
Master of Science Report or Thesis	8 QH	4 QH	0 QH
Elective Courses	13 QH	17 QH	21 QH
Minimum Quarter Hours Required**	**40 QH**	**40 QH**	**40 QH**

* This option is not available to students who receive financial support from the University as research assistants, teaching assistants, or in the form of tuition assistance.

** Exclusive of any preparatory courses.

Required Core Courses

				Credits
	CIV	3201	Construction Management	4
	CIV	3202	Legal Aspects of Civil Engineering	4
	CIV	3245	Construction Seminar	2
	CIV	3252	Construction Project Control and Organization	2
	ACC	3301	Financial and Managerial Accounting	3
Or	ACC	3820	Financial Accounting	3
	MIM	3400	Basic Probability and Statistics	4
	CIV	3850	Master of Science Report	4
	CIV	3860	Master of Science Thesis	8

The remaining 13 to 21 quarter hours of elective course work must be selected from the following list. Electives do not have to be chosen from only one area.

Construction and Engineering Emphasis

			Credits
CIV	3203	Construction Equipment and Modeling	4
CIV	3401	Advanced Soil Mechanics	4
CIV	3402	Advanced Foundation Engineering	4
CIV	3508	Advanced Materials	4

Business Management Emphasis

			Credits
FIN	3301	Financial Analysis	3
FIN	3916	Valuation and Value Creation	3
MIM	3204	Engineering/Organizational Psychology	4
MIM	3207	Financial Management for Engineers	4

Systems Engineering Emphasis

		Credits
MIM 3102	Planning and Managing Information Systems Development	4
MIM 3104	Data Structures	4
MIM 3115	Introduction to Software Engineering and Computer Technology	4
MIM 3122	PC Architecture and System Programming	4
MIM 3128	Database Management Systems	4
MIM 3129	Expert Systems in Engineering	4
MIM 3425	Introduction to Reliability Analysis and Risk Assessment	4
MIM 3503	Simulation Methodology and Applications	4
MIM 3524	Multi-Criteria Decision Making	4
MIM 3530	Operations Research I	4

Environmental Engineering

The Graduate Program in Environmental Engineering consists of required core courses and elective courses as described below. With the approval of the program adviser, students may take other graduate courses in civil engineering, in other engineering disciplines, or in other colleges at Northeastern.

Course Requirements	With Thesis	With Report	Course work Only *
Required Core Courses	16 QH	16 QH	16 QH
Master of Science Report or Thesis	8 QH	4 QH	0 QH
Elective Courses	16 QH	20 QH	24 QH
Minimum Quarter Hours Required**	**40 QH**	**40 QH**	**40 QH**

* This option is not available to students who receive financial support from the University as research assistants, teaching assistants, or in the form of tuition assistance.

** Exclusive of any preparatory courses.

Required Core Courses (2 QH equivalents are in parentheses)

		Credits
CIV 3312	Environmental Chemistry	4
CIV 3318	Water and Wastewater Treatment	4
CIV 3321	Environmental Biological Processes	4
CIV 3327	(3325 & 3326) Environmental Laboratory	4
CIV 3850	Master of Science Report	4
CIV 3860	Master of Science Thesis	8

The remaining sixteen to twenty-four quarter hours of elective course work must be selected from three elective groupings: Environmental Engineering, Environmental Science, and General Engineering as listed below. Other graduate courses in the University may also be accepted with the approval of the faculty adviser. Electives do not have to be chosen from only one area.

Environmental Engineering

			Credits
CIV	3301	Surface Water Hydrology and Contaminant Transport	4
CIV	3302	Groundwater Hydrology and Contaminant Transport	4
CIV	3303	Groundwater Modeling	4
CIV	3304	Advanced Wastewater Treatment and Industrial Waste Processes	4

Environmental Science

			Credits
CIV	3305	Solid and Hazardous Waste Management Practices	4
CIV	3306	Air Pollution	4
CIV	3307	Environmental Protection and Management	4

General Engineering

			Credits
CIV	3201	Construction Management	4
CIV	3202	Legal Aspects of Civil Engineering	4
CIV	3407	Engineering Geology	4
MIM	3400	Basic Probability and Statistics	4
MIM	3423	Applied Statistics	4

Geotechnical/Geoenvironmental Engineering

The Geotechnical Engineering program includes study in the areas of Soil Mechanics/Foundations and Geoenvironmental Engineering. Beginning with a core of required courses that provide a basic geotechnical background for all students, each student is able to select courses from both of the two elective areas in order to concentrate their professional interest. Geotechnical engineering students are also encouraged to select courses offered in the Structural Engineering program. Each student must meet with their faculty adviser at the beginning of their program to select an appropriate sequence of courses.

Course Requirements	With Thesis	With Report	Course work Only *
Required Core Courses	12 QH	12 QH	12 QH
Master of Science Report or Thesis	8 QH	4 QH	0 QH
Elective Courses	20 QH	24 QH	28 QH
Minimum Quarter Hours Required**	**40 QH**	**40 QH**	**40 QH**

* This option is not available to students who receive financial support from the University as research assistants, teaching assistants, or in the form of tuition assistance.

** Exclusive of any preparatory courses.

Required Core Courses

			Credits
CIV	3302	Groundwater Hydrology and Contaminant Transport	4
CIV	3401	Advanced Soil Mechanics	4
CIV	3402	Advanced Foundation Engineering	4
CIV	3850	Master of Science Report	4
CIV	3860	Master of Science Thesis	8

Soil Mechanics/Foundations Electives

			Credits
CIV	3203	Construction Equipment and Modeling	4
CIV	3303	Groundwater Modeling	4
CIV	3403	Seepage and Stability	4
CIV	3404	Introduction to Dynamics and Earthquake Engineering	4
CIV	3405	Soil Dynamics	4
CIV	3406	Earthquake Engineering	4
CIV	3407	Engineering Geology	4

Geoenvironmental Engineering Electives

			Credits
CIV	3301	Surface Water Hydrology and Contaminant Transport	4
CIV	3303	Groundwater Modeling	4
CIV	3305	Solid and Hazardous Waste Management Practices	4
CIV	3312	Environmental Chemistry	4
CIV	3321	Environmental Biological Processes	4
CIV	3327	Environmental Laboratory	4
CIV	3407	Engineering Geology	4

Additional Electives

			Credits
CIV	3202	Legal Aspects of Civil Engineering	4
CIV	3501	Advanced Structural Analysis	4
CIV	3503	Structural Dynamics	4
MIM	3010	Numerical Methods in Mechanical Engineering	4
MIM	3400	Basic Probability and Statistics	4
MIM	3425	Introduction to Reliability Analysis and Risk Assessment	4
MIM	3690	The Finite Element Method	4

Structural Engineering

The Structural Engineering program includes courses in the areas of structural mechanics, structural analysis and design, dynamics of structures, and earthquake engineering. Students pursuing a Master's Degree in Structural Engineering can select, with their adviser, a course sequence with an analytical or design focus.

Course work includes courses selected from a list of Restricted Electives and Other Electives. Each student must meet with their adviser in the first quarter of study for advice and approval on a program that is best fitted to their interests and objectives.

Course Requirements	With Thesis	With Report	Course work Only *
Restricted Electives	20 QH	24 QH	28 QH
Master of Science Report or Thesis	8 QH	4 QH	0 QH
Other Electives	12 QH	12 QH	12 QH
Minimum Quarter Hours Required**	**40 QH**	**40 QH**	**40 QH**

* This option is not available to students who receive financial support from the University as research assistants, teaching assistants, or in the form of tuition assistance.

** Exclusive of any preparatory courses.

Restricted Electives

			Credits
CIV	3101	Applied Probability	4
CIV	3401	Advanced Soil Mechanics	4
CIV	3402	Advanced Foundation Engineering	4
CIV	3404	Introduction to Dynamics and Earthquake Engineering	4
CIV	3405	Soil Dynamics	4
CIV	3406	Earthquake Engineering	4
CIV	3501	Advanced Structural Analysis	4
CIV	3502	Advanced Mechanics	4
CIV	3503	Structural Dynamics	4
CIV	3504	Seismic Analysis and Design	4
CIV	3505	Behavior of Reinforced Concrete Structures	4
CIV	3506	Behavior of Steel Structures	4
CIV	3507	Design of Pre-stressed Concrete Structures	4
CIV	3508	Advanced Materials	4
CIV	3509	Stability	4
MIM	3400	Basic Probability and Statistics	4
CIV	3850	Master of Science Report	4
CIV	3860	Master of Science Thesis	8

Other Electives

Other electives may include any graduate course from the Department of Civil and Environmental Engineering or any of the following courses. Other graduate engineering courses may be requested by petition.

Analytical Orientation

			Credits
MIM	3000	Mathematical Methods for Mechanical Engineers	4
MIM	3010	Numerical Methods in Mechanical Engineering	4
MIM	3425	Introduction to Reliability Analysis and Risk Assessment	4
MIM	3600	Theory of Elasticity	4
MIM	3625	Advanced Dynamics	4
MIM	3630	Vibration Theory and Applications	4
MIM	3650	Automatic Control Engineering	4
MIM	3690	The Finite Element Method	4

Design Orientation

			Credits
MIM	3350	Computer Aided Graphics and Design	4
MIM	3665	Engineering Fracture Mechanics	4
MIM	3825	Electronic Behavior 1	4

Transportation Engineering

The Transportation Engineering program is designed for students with career goals in transportation engineering and transportation planning. The program consists of a core of courses in transportation planning and engineering, supported by related courses in applied mathematics, engineering, economics, policy, and management.

Course Requirements	With Thesis	With Report	Course work Only *
Required Core Courses	12 QH	12 QH	12 QH
Restricted Electives	8 QH	8 QH	12 QH
Other Electives	12 QH	16 QH	16 QH
Master of Science Report or Thesis	8 QH	4 QH	0 QH
Minimum Quarter Hours Required **	**40 QH**	**40 QH**	**40 QH**

* This option is not available to students who receive financial support from the University as research assistants, teaching assistants, or in the form of tuition assistance.

** Exclusive of any preparatory courses.

Required Core Courses

			Credits
CIV	3607	Traffic Engineering	4
CIV	3642	Transportation Planning	4
MIM	3400	Basic Probability and Statistics	4
CIV	3850	Master of Science Report	4
CIV	3860	Master of Science Thesis	8

Restricted Electives

			Credits
CIV	3602	Transportation Demand Models	4
CIV	3603	Transportation Supply Models	4
CIV	3612	Public Transportation	4
CIV	3636	Transportation Engineering	4
MIM	3423	Applied Statistics	4
MIM	3503	Simulation Methodology and Applications	4

Other Electives

Students may take any course from the Restricted Elective list, or any adviser-approved graduate course related to transportation engineering. Courses may be in areas including, but not limited to, operations research, construction and project management, information systems, economics, and air pollution.

THE DOCTOR OF PHILOSOPHY DEGREE

Award of the Doctor of Philosophy degree is based on exceptional performance in course work and evidence of ability to formulate and execute original research. The degree program has two components: (1) An academic program consisting of a set of graduate level courses which provide depth in a specific area of Civil Engineering (the major field) and additional exposure at an advanced level to one or more science disciplines (the minor field); and (2) the doctoral dissertation, an extended independent research effort on a relevant technical problem resulting in an original contribution.

Mastery of the subject matter is measured by a qualifying examination covering a subset of subjects selected from the major field. Research progress is monitored periodically by a Doctoral Dissertation Committee and the candidate is required to present and defend the research results before an expanded group of faculty and research staff at the completion of the work.

The doctoral program is deliberately designed to be flexible with respect to subject area since the PhD degree is primarily a "research" degree and therefore the program must be adaptable to changes in research needs.

Qualifying Examination and Degree Candidacy

The qualifying examination consists of written and oral components. Its content depends on the educational background and objectives of the student. In general, the written component covers subject matter at the Master's level selected from the major field and includes basic engineering and science disciplines as well as civil engineering application areas. The oral component measures general comprehension and aptitude for research. If the examination is failed, it may be repeated by permission of the Qualifying Examination Committee. The qualifying examination shall be administered within the first eighteen months after the start of the student's PhD program. After successful completion of the examination and upon satisfaction of the general graduate school regulations, the student is classified as a doctoral candidate. The defense of the doctoral dissertation shall be administered within seven years from the starting date of the student's PhD program.

Course Requirements

A proposal defining the content of the academic program is developed jointly by the student and faculty adviser and then reviewed by the Qualifying Examination Committee. Intellectual rigor, connectivity of subject matter, and compatibility with departmental interests are critical issues. Final approval is arrived at through discussion and represents a mutual agreement between the student and the PhD Committee. Flexibility in program definition is encouraged, especially in areas where complementary courses exist in other departments, or where expertise resides outside the department and the objective is to introduce new technology in civil engineering practice.

The academic program must contain at least seventy-two quarter hours of graduate level course work. No more than four quarter hours of CIV3835 (Special Project in Civil Engineering) may be counted toward the PhD program. A minimum of sixty quarter hours must be related to the major field but may include courses from other departments when appropriate. The minor field must include a minimum of twelve quarter hours of course work in science disciplines of interest to civil engineers, e.g., mathematics, computer science, materials science, earth sciences, chemistry, biology, health sciences. Upon successful completion of the PhD qualifying examination and the majority of required course work, the student is required to register in three consecutive quarters for CIV3880 (PhD Thesis). Upon completion of this sequence, the student is required to register for CIV3799 (PhD Continuation) in every quarter until the dissertation is completed. Students may not register for continuation until the three quarter thesis sequence has been fulfilled.

Students with an MS degree will receive thirty-six quarter hours of credit toward the PhD program. A minimum of twenty-eight quarter hours of course work beyond the MS degree must be completed at Northeastern University.

Language Requirement

The candidate must be proficient in technical writing and oral presentation in the English language. Appropriate course work may be required by the Qualifying Examination Committee.

Residence Requirement

Three successive quarters of full-time study on campus are required to establish residence. The total effort for a doctorate involves a minimum of three years of full-time work beyond the Bachelor's Degree. Candidates who enter the doctoral program with a Master of Science Degree may complete the requirements in less time, but they should anticipate at least two years of full-time effort.

Dissertation

Once degree candidacy has been established, the student is allowed to proceed with the dissertation effort. The candidate is required to generate a dissertation proposal and identify a civil engineering faculty member who will act as the Dissertation Adviser. A Dissertation Committee formed by the student and their research supervisor will monitor progress and approve the final document. The Dissertation Committee shall have no fewer than four members, of which at least three shall be full-time faculty from the Civil and Environmental Engineering Department.

Comprehensive Examination

The comprehensive examination consists of a defense of the doctoral research work and an examination on subject matter related to the dissertation area.

FACULTY

Peter G. Furth, Chairman

Professors

Furth, Peter G., PhD, Massachusetts Institute of Technology; transportation analysis and planning, traffic and transit engineering optimization, applied probability and statistics

Novotny, Vladimir, PhD. PE, Camp Dresser McKee Professor, Vanderbilt University, environmental and water resources engineering

Yegian, Mishac K., PhD, PE, Massachusetts Institute of Technology; soil dynamics, earthquake engineering, risk analysis. geotechnical engineering, geosynthetics, seismic response of waste containments

Associate Professors

Alshawabkeh, Akram N., PhD, Louisiana State University; geotechnical and geoenvironmental engineering, soil remediation, electrokinetic processing, contaminant fate and transport.numerical modeling

Bernal, Dionisio, PhD, University of Tennessee; earthquake engineering, structural engineering

Langseth, David E., ScD, PE, Massachusetts Institute of Technology; environmental engineering, water resources and water quality remediation; risk management

Scranton, Richard J., MS, Massachusetts Institute of Technology; transportation systems, mechanics. applied probability

Sheahan, Thomas C., ScD, PE, Massachusetts Institute of Technology; geotechnical engineering, clay behavior, laboratory equipment automation, and measurement instrumentation

Touran, Ali, PhD, PE, Stanford University; construction engineering and management

Wadia-Fascetti, Sara, PhD, Stanford University; structural engineering, structural dynamics, applications to infrastructure and deteriorating structures, earthquake ground motions, condition assessment

Wei, Irvine W., PhD, Harvard University; water chemistry, treatment processes, acid precipitation

Assistant Professors

Sasani, Mehrdad, PhD, University of California at Berkeley; Earthquake Engineering, Reliability and Performance-Based Engineering, Reliability Based Seismic Codes, Experimental and Analytical Studies on Reinforced Concrete Structures and Energy Dissipating Devices

Wang, James Y., PhD, North Carolina State University; environmental engineering, integrated waste management and environmental remediation, microbiological processes of solid and hazardous waste management

Program Advisers

	Full-time	**Part-time**
Construction	Professor Ali Touran	Professor Ali Touran
Environmental	Professor Irvine W. Wei	Professor Irvine W. Wei
Geotechnical	Professor Mishac K. Yegian	Professor Mishac K. Yegian
Structural	Professor Akram N. Alshawabkeh	Professor Akram N. Alshawabkeh
Transportation	Professor Peter G. Furth	Professor Peter G. Furth

Each course description includes information on the expected quarter in which classes are usually offered. The quarters listed are presented here for planning purposes; however, the Graduate School of Engineering cannot guarantee that all courses will be offered. Students must refer to the Graduate School of Engineering Quarterly Course Offering booklets to determine what courses are actually offered in any given quarter.

CIV 3101 Applied Probability (4QH)
Fall Quarter

Review of fundamental probability concepts, including conditional probability, expectation, and covariance. Probability distributions commonly used in Civil Engineering. Simple reliability models. Derived distributions. Maximum Likelihood Estimation. Sampling distributions. Confidence intervals and hypothesis testing. Goodness of fit. Focus is on modeling applications in Civil Engineering. *Prerequisite: Undergraduate course in probability or permission of instructor.*

CIV 3132 Engineering Statistics (2QH)
Winter Quarter, Alternate years

Sampling techniques, including stratified sampling, two-stage sampling, and ratio estimation. Linear regression. Focus is on statistical applications in Civil Engineering. *Prerequisite: CIV 3101, MIM 3400, or undergraduate course in probability with permission of instructor.*

CIV 3201 Construction Management (4QH)
Fall Quarter

A presentation of all aspects of Construction Management; industry profile, parties involved, contracts, bonds, bidding, changes, preplanning, CM approach and partnering. Another area of emphasis is planning and scheduling, network-based scheduling systems (CPM), resource management, network acceleration, PERT probabilistic approach, WBS and work packaging. Students will use a software package as part of the requirements. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3202 Legal Aspects of Civil Engineering (4QH)
Spring Quarter

A presentation of U.S. and International legal systems and theories necessary for the comprehension of business and contractual liabilities, rights and obligations in the engineering field. Description and evaluation of various types of construction contracts, procedures and formats for submitting bids, filing claims, and legal steps to avoid liabilities. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3203 Construction Equipment and Modeling (4QH)
Winter Quarter

Selection and application of construction equipment; earthmoving equipment including excavators, bulldozers, scrapers, *etc.*; belt-conveyor systems, bituminous pavements material and equipment. Productivity analysis of equipment operations, equipment economics, computer modeling of equipment production systems including truck-loader, scraper-tractor; simulation of construction operations. Students will use a software package for simulation. *Prerequisite: CIV 3101 or CIV 3132.*

CIV 3245 Construction Seminar (2QH)
Spring Quarter

A reading and discussion course centering on recent research publications in Construction Engineering. *Prerequisite: Limited to Construction Management program majors.*

CIV 3252 Construction Project Control and Organization (2QH)
Winter Quarter

Organization of construction firms both at the general corporate level and at the project level. Organization dynamics designed to respond to the requirements of the environment given the internal constraints of the firm. Computer systems for the control of construction projects. Design attributes to fit the needs of the organization and the end users. Estimating, scheduling, budgeting and financial control of projects. Network-based systems for planning and time control. Intra-project and inter-project resource allocation. Database design concepts for decision support systems. *Prerequisite: CIV 3201.*

CIV 3301 Surface Water Hydrology and Contaminant Transport (4QH)
Fall Quarter

Analysis of hydrologic processes for selected engineering applications. Topics include hydrographic analysis, rainfall-runoff, routing, urban hydrology, storage analysis, hydrologic design. Effects of pollutant discharges into surface water bodies, principles of water quality modeling in lakes, rivers and coastal areas, mixing in estuaries and embayments, models of reservoirs and ponds, stratification in lakes and reservoirs, sediment transport, nutrient cycling and eutrophication, case studies. *Prerequisites: Admission to the Graduate School of Engineering, CIV 1320 (Hydraulic Engineering).*

CIV 3302 Groundwater Hydrology and Contaminant Transport (4QH)
Winter Quarter

Covers the fundamentals of the flow of groundwater and its importance as a water resource. Topics include: porous media characteristics, Darcy's equation, non-linear resistance, the groundwater flow equations, spatial averaging simplifications, aquifer storage and transmissivity, transient flow in aquifers, well hydraulics, pump test analysis. Contaminant transport in groundwater, advection and dispersion, reactive transport. Multiple phase flow, unsaturated flow and transport. *Prerequisites: Admission to the Graduate School of Engineering, CIV 1320 (Hydraulic Engineering).*

CIV 3303 Groundwater Modeling (4QH)
Spring Quarter

Computational modeling of groundwater flow and contaminant transport. Topics include mass balance equations, fluxes and reactive transport, conceptual models. Groundwater flow

modeling. Finite difference and finite element methods. Numerical modeling of contaminant transport. Data requirements, implementation of singularities in flow and transport, calibration targets, sensitivity analyses, limitations of models, public domain codes, case studies. Students must be familiarized with numerical solutions to systems of algebraic equations. *Prerequisite: CIV 3302.*

CIV 3304 Advanced Wastewater Treatment and Industrial Waste Processes (4QH)
Spring Quarter

An examination of industrial waste problems with design considerations for industrial solids and liquid wastes is combined with unit operations and processes used for advanced wastewater treatment systems design. Representative topics included are: industrial waste characterization, industrial waste survey techniques, residuals management, nitrification, biological nutrient removal, chemical treatment technologies, land treatment, waste reduction, membrane technologies and recycle or reuse of liquid and solid streams. *Prerequisite: CIV 3318.*

CIV 3305 Solid and Hazardous Waste Management Practices (4QH)
Winter Quarter

Integrated solid waste management for engineering and science students combined with the principles of hazardous waste management and site remediation technology. Topic areas include: waste generation, waste properties, waste classification, collection systems, transformation, recycling, thermal conversion, landfilling, and site remediation technologies such as bioremediation, air stripping, and vapor extraction. *Prerequisite: CIV 3318.*

CIV 3306 Air Pollution (4QH)
Winter Quarter

Theory and practice related to engineering management of air resources, applications of models for atmospheric dispersion of pollutants; analysis of control systems for gaseous and particulate emissions utilizing dry collection, wet collection, absorption and catalytic processes. Discussion of source control and air quality standards. Part of the course focuses on biological and chemical aspects of air pollution with emphasis on toxicological aspects, physiological effects of aerosols, analysis of organic and inorganic constituents of the atmosphere and rational for establishing air quality criteria and standards. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3307 Environmental Protection and Management (4QH)
Spring Quarter

Current environmental problems are analyzed through use of case studies, role-playing and computer simulation. Topics illustrate management of specific environmental systems such as solid and hazardous waste facilities, wastewater treatment, incineration and septic systems. A broad range of environmental issues are included, ranging from resource management to aspects of thermal and noise pollution. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3312 Environmental Chemistry (4QH)
Fall Quarter

A review of chemistry with applications to environmental engineering including: properties of water and pollutants, acid-base reactions, pH, alkalinity, equilibrium chemistry, chemical kinetics, chemical thermodynamics, coordination chemistry, precipitation-dissolution reactions, surface chemistry, adsorption-desorption, redox reactions and organic chemistry as it relates to the environment. *Prerequisite: Two quarters of general chemistry.*

CIV 3318 Water and Wastewater Treatment (4QH)
Fall and Winter Quarters

Design principles and theory of removal of impurities from water are covered. Treatment unit operations and processes typically include: packed tower aeration, screening, coagulation and flocculation, sedimentation, filtration, ion exchange, activated carbon adsorption and disinfection. Wastewater treatment with emphasis on secondary municipal treatment processes is covered including: preliminary treatment, primary clarification, activated sludge systems, aerated lagoons, aeration and mixing theory, fixed film biological treatment systems, anaerobic treatment systems and wastewater reuse. *Prerequisite: Undergraduate fluid mechanics, CIV 3321 should be taken before or concurrently.*

CIV 3321 Environmental Biological Processes (4QH)
Winter Quarter

A study of microbiology with emphasis on biological importance in environmental engineering applications. Topics include cell structure, cell nutrition, cell chemistry, morphology, aerobic and anaerobic microbial metabolism, major metabolic pathways, biological wastewater process theory and kinetics, nitrification, denitrification, pathogens, and effects of environment on microbial populations. *Prerequisite: CIV 3312.*

CIV 3324 Hazardous Waste Management (4QH)
As Announced

Introduce various aspects of hazardous waste management including environmental remediation. The course will include engineering principles as well as socioeconomic and regulatory issues surrounding the hazardous waste management. The course will provide sufficient background to enable the student to understand, evaluate, and critique the design of the decisions in various waste management alternatives. Topic areas include: waste characterization, environmental compliance and pollution prevention, site assessment, waste treatment, and remediation engineering. *Prerequisite: CIV 3321.*

CIV 3325 Environmental Chemistry Laboratory (2QH)
Winter Quarter

A laboratory course emphasizing analysis related to important topics in environmental chemistry including acid-base reactions, chemical kinetics, precipitation reaction, coordination chemistry, and oxidation-reduction reactions. Analytical techniques include colorimetry, gravimetric and electrochemical methods, atomic absorption spectrophotometry, and gas chromatography. *Prerequisite: CIV 3312.*

CIV 3326 Biological Processes Laboratory (2QH)
Spring Quarter

A laboratory course emphasizing analysis related to microbiological examination and other treatment parameters used to monitor the biological process such as: BOD, TOC, COD,

gravimetric methods and dissolved oxygen. Enzyme kinetics and evaluation of kinetic coefficients for biotreatment will be covered. *Prerequisites: CIV 3321 and CIV 3325.*

CIV 3327 Environmental Laboratory (4QH)
Fall Quarter

Embodies the material in CIV 3325 and CIV 3326. *Prerequisites: CIV 3312 (or to be taken concurrently with CIV 3312) and CIV 3321.*

CIV 3328 Integrated Solid Waste Managment (4QH)
Fall Quarter

Introduces various aspects of an integrated solid waste management system. The course will include engineering principles as well as socioeconomic and regulatory issues surrounding solid waste management. The course will provide sufficient background to enable the student to understand, evaluate, and critique the design of and the decisions associated with various waste management alternatives. Topic areas include: waste generation and source reduction, waste processing and recycling, waste collection and transportation, landfill engineering, incineration, and composting. *Prerequisite: CIV 3321.*

CIV 3332 Environmental Computer Applications (2QH)
Fall Quarter

Fundamental principles of deterministic and stochastic modeling applied to environmental problems. Utilization of mathematical software for the development of computer models and simulation related to treatment plant performance, stream and lake modeling and contaminant dispersion in air, water, and soil. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3372 Air Sampling And Analysis (2QH)
Fall Quarter

Basic design considerations and requirements for air quality surveillance. Examination of the methodologies for air quality sampling, sampling frequencies, measurement techniques and data acquisition, handling and analysis. Manual and automated techniques are discussed for the evaluation of source and ambient systems. Statistical techniques are employed to evaluate air quality management strategies. *Prerequisite: CIV 3306.*

CIV 3401 Advanced Soil Mechanics (4QH)
Fall Quarter

Characterization of soils, soil mineralogy and chemistry, stresses within a soil mass, basic porous media flow principles, effective stress principle, compaction, drained and undrained stress-strain-strength concepts, consolidation theory and its applications. *Prerequisite: Admission to the Graduate School of Engineering, or permission of instructor.*

CIV 3402 Advanced Foundation Engineering (4QH)
Winter Quarter

Bearing capacity and settlement analysis of conventional shallow foundations and combined footings; mat design; lateral earth pressure theory and application to retaining wall design; braced excavations, sheet pile wall design, slurry trench walls; bearing capacity design and analysis for deep foundations; laterally loaded piles, friction piles, and pile driving analysis. *Prerequisite: CIV 3401.*

CIV 3403 Seepage and Stability (4QH)
Spring Quarter, Alternate years

Analysis of seepage, confined and unconfined flow. Finite element method, computer applications. Drained and undrained behavior of soils, and long-term and short-term effects on shear stress-strain-strength. Slope and embankment stability analysis with computer applications. Embankments on soft clays. *Prerequisite: CIV 3401.*

CIV 3404 Introduction to Dynamics and Earthquake Engineering (4QH)
Fall Quarter

Dynamic forces in Civil Engineering; ground vibrations, blast vibrations. Dynamics of single-degree-of-freedom systems, seismicity, earthquake ground vibrations, response spectrum, wave propagation, site effects on ground motion, design response spectra. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3405 Soil Dynamics (4QH)
Winter Quarter, Alternate years

Dynamics of single mass, multi-degree-of-freedom systems. Design of foundations for dynamic loads. Dynamics soil properties, laboratory and field measurements, liquefaction. *Prerequisite: CIV 3404.*

CIV 3406 Earthquake Engineering (4QH)
Spring Quarter, Alternate years

Seismic sources, ground motion attenuation, seismic hazard analysis, design ground motions, soil-structure interaction, structural response, seismic design of buildings, earth retaining structures, earth dams and landfills. *Prerequisite: CIV 3404.*

CIV 3407 Engineering Geology (4QH)
Spring Quarter, Alternate years

Selected topics in historical and structural geology related to engineering geology; origin and occurrence of various rock types, geologic structures, faulting and joint systems; weathering of rock and weathering products, glaciation, geologic mapping and environmental aspects; case studies. *Prerequisite: Undergraduate course in geology.*

CIV 3408 Geoenvironmental Engineering (4QH)
As Announced

Definitions and regulations, soil formation and mineralogy, hydraulic conductivity measurements, reactive contaminant transport through fine grained soils, landfill and liners design, seepage barriers and cutoff walls, introduction to site characterization and remediation. *Prerequisite: Undergraduate degree or permission of instructor.*

CIV 3501 Advanced Structural Analysis (4QH)
Fall Quarter

Formulation and solution of structural problems with primary application to member systems (trusses, frames, curved members), matrix formulation of flexibility and stiffness methods, geometrically nonlinear behavior, static condensation, substructuring, multiple structural systems, introduction to energy methods. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3502 Advanced Mechanics (4QH)
Spring Quarter

Analysis of force equilibrium (stress), deformation/displacement (strain), and force/deformation (Hooke's Law) for an elastic solid; compatibility; governing equations for complete and approximate elasticity solution. Plane stress solution for narrow rectangular beams. Torsion, Saint Venant's theory, membrane analogy, rectangular sections, thin open and closed sections. Introduction to bending of thin plates. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3503 Structural Dynamics (4QH)
Winter Quarter

Solution techniques for linear SDOF systems: convolution, analysis in the frequency domain, numerical integration, relationship between time and frequency domain procedures. Nonlinear SDOF systems. Formulation of equations of motion for discrete multi-degree-of-freedom linear systems. Generation of mass, stiffness and damping matrices, static condensation. Calculation of mode shapes and natural frequencies. Analysis of linear response in mode shapes and natural frequencies. Analysis of linear response in modal coordinates. Direct integration of equations of motion. The response spectrum method in modal analysis. *Prerequisites: CIV 3501 and CIV 3502.*

CIV 3504 Seismic Analysis and Design (4QH)
Spring Quarter, Alternate years

Formulation of equations of motion for multi-support excitation. Soil-Structure Interaction. Torsional response. Inelastic response spectra. Computation of inelastic response in MDOF systems. Dynamic Instability. Earthquake considerations in building design. Seismic code provisions. *Prerequisites: CIV 3404 and CIV 3503.*

CIV 3505 Behavior of Reinforced Concrete Structures (4QH)
Spring Quarter, Alternate years

Moment-curvature relationships for reinforced concrete cross sections; effect of design parameters in resulting behavior; ductility; moment-curvature and load-deflection relationships for reinforced concrete beams; effective stiffness, combined bending and axial load, shear and axial load, shear and torsion. Relation between research results and specifications for design. *Prerequisite: Undergraduate Concrete Design.*

CIV 3506 Behavior of Steel Structures (4QH)
Spring Quarter, Alternate years

Behavior of structural steel members due to static and fatigue loading, simple shear and moment connections for beams; composite columns and beam columns, development of column strength curves; buckling about weak and strong axes. Slender compression elements; brittle fracture; torsion. *Prerequisite: Undergraduate Steel Design.*

CIV 3507 Design of Pre-stressed Concrete Structures (4QH)
Winter Quarter, Alternate years

Properties of pre-stressing materials; methods of pretensioning and posttensioning; prestress losses; analysis and design of simple and continuous beams and slabs for flexure and shear, camber, deflection and crack control, prestressed column design, load balancing method for analysis of indeterminate prestressed structure. Behavior of prestressed concrete beams and columns. *Prerequisite: Undergraduate Concrete Design.*

CIV 3508 Advanced Materials (4QH)
Winter Quarter, Alternate years

Concrete components and microstructure including: chemical, physical, and micro-structural properties of cement hydration; role of water, effect of water quality and sulfate attack; aggregate type and properties, possible problems with aggregates (including alkali-aggregate reaction). Behavior of hardened concrete including: factors affecting concrete strength; effects of temperature, creep and shrinkage; non-structural cracking, curing of hardened concrete; corrosion of steel in concrete, durability. Special Portland and non-Portland cements, admixtures, special concretes. *Prerequisite: Undergraduate Civil Engineering Materials.*

CIV 3509 Stability (4QH)
Spring Quarter, Alternate years

Elastic stability of columns. Principle of minimum potential energy. Buckling analysis of rigid frames. Second order analysis of frames using stability functions. Numerical methods in stability. *Prerequisite: CIV 3501.*

CIV 3513 Structural Reliability (4QH)
As Announced

Introduction to probability theory and random variables. Formulation of reliability for structural components and systems. Exact solutions, first and second-order reliability methods, simulation methods. Analysis of model uncertainty. Stochastic load and resistance models. Bases for probabilistic structural codes. Tim e-dependent reliability methods. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3602 Transportation Demand Models (4QH)
Winter Quarter, Alternate years

Trip generation models, including cross-classification and regression models. Trip distribution models, including gravity models and various methods of matrix estimation. Mode choice models, including logit models, nested logit, and incremental prediction. Elasticity and direct demand models. *Prerequisites: CIV 3101 or MIM 3400, CIV 3642.*

CIV 3603 Transportation Supply Models (4QH)
Spring Quarter, Alternate years

Important models of transportation system performance and transportation system design. Delay models for intersections and freeways. Shortest path models. Traffic assignment models, including equilibrium assignment. Traffic signal timing algorithms. Supporting non-linear optimization methods including interval reduction, convex combinations, Kuhn-Tucker conditions, and dynamic programming. *Prerequisite: Multivariate Calculus.*

CIV 3607 Traffic Engineering (4QH)
Spring Quarter

Traffic flow theory and measurement. Capacity and level of service analysis for intersections, arterials, and highways. Intersection design. Traffic analysis and design software. Transportation systems management. *Prerequisite: Admission to the Graduate School of Engineering.*

CIV 3610 Urban Public Transportation (2QH)
Spring Quarter

Analysis and planning of public transportation systems, including bus, subway, commuter rail, and paratransit. Performance models; service evaluation and monitoring; data collection; service design; demand prediction; institutional and economic issues. *Prerequisite: CIV 3101 or MIM 3400.*

CIV 3612 Public Transportation (4QH)
As Announced

Analysis, planning, and operational design of public transportation systems including bus and rail transit. Service design and scheduling; data collection and service quality monitoring; sampling; demand prediction; passenger flow modeling; performance, cost, and design models; institutional and economic issues. *Prerequisite: CIV 3101 or MIM 3400.*

CIV 3636 Transportation Engineering (4QH)
As Announced

Analysis and design of transportation facilities for rail (including public transportation), air, and water modes.

CIV 3642 Transportation Planning (4QH)
Fall Quarter, Alternate Years

Introduction to transportation planning for both the short term and long term. Travel demand forecasting, including trip generation, trip distribution, modal split, and network assignment. Demand elasticity. Transit route scheduling. Alternatives evaluation, including environmental impact, economic comparison, and financial impact. *Prerequisite: Undergraduate Calculus.*

CIV 3798 Master's Continuation (0QH)
Any Quarter

CIV 3799 PhD Continuation (0QH)
Any Quarter

CIV 3830 Special Topic in Civil Engineering (2QH)
Fall, Winter and Spring Quarters

This course is offered when the need for a special topic is evident to faculty and students. The course is initiated by the appropriate faculty members and discipline committee and approved by the department. *Prerequisite: Permission of the Instructor.*

CIV 3831 Special Topic in Civil Engineering (4QH)
Fall, Winter, and Spring Quarters

This course is offered when the need for a special topic is evident to faculty and students. The course is initiated by the appropriate faculty members and discipline committee and approved by the department. *Prerequisite: Permission of the Instructor.*

CIV 3835 Independent Study/Project (2QH)
(Formerly Special Project in Civil Engineering)
Any Quarter

An individual effort in an area selected by student and adviser and approved by the Department Discipline Committee resulting in a definitive report. *Prerequisite: Permission of the department.*

CIV 3836 Independent Study/Project (4QH)
Any Quarter

An individual effort in an area selected by student and adviser and approved by the Department Discipline Committee resulting in a definitive report. *Prerequisite: Permission of the department.*

CIV 3850 Master's Report (4QH)
Any Quarter

An individual effort consisting of laboratory and/or literature investigation and analysis or advanced design of a project in an area of civil engineering selected by student and adviser resulting in a definitive report. *Please note: MS students have 7 years from matriculation to finish all degree requirements, and they must register for MS Continuation each quarter until MS Report is completed. Prerequisite: Permission of the department.*

CIV 3851 Master's Report (2QH)
Any Quarter

CIV 3860 Master's Thesis (8QH)
Any Quarter

Analytical and/or experimental research conducted by arrangement with and under the supervision of the department. *Prerequisite: Permission of the department.*

CIV 3861 Master's Thesis (4QH)
Any Quarter

CIV 3862 Master's Thesis (2QH)
Any Quarter

CIV 3880 PhD Thesis (0QH)
Any Quarter

Open to full-time Doctoral students only. *Prerequisite: Admission to doctoral program in Civil Engineering.*

Computer Systems Engineering

The Graduate School of Engineering offers an interdisciplinary program leading to the degree of Master of Science in Computer Systems Engineering. This program includes courses drawn from the Department of Electrical and Computer Engineering, the Department of Mechanical, Industrial and Manufacturing Engineering, and the College of Computer Science.

The program may be pursued on a full- or part-time basis. Students may select courses from both day and evening offerings. Students must select one of the following areas of concentration within the program:

Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM)
Engineering Software Design (ESD)

Students admitted into this program are assigned a faculty adviser depending upon the area of concentration selected.

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of forty-eight quarter hours of graduate course work with a minimum grade point average of 3.000 is required to receive the degree. Refer to the regulations in this catalog for detailed information on academic and administrative policies.

Students holding an engineering degree from an ABET-accredited institution will qualify to apply for the Master of Science in Computer Systems Engineering. Students with a Bachelor of Science in the physical sciences may also apply. A Graduate Record Examination (GRE) may be required.

Prerequisite Courses

Students are expected to be proficient in the C programming language. Other prerequisites may be required of students in each concentration area. The following prerequisites are required, and up to four quarter hours of these courses may be applied to the forty-eight quarter hour minimum degree requirement. Determination of prerequisite needs will be made at the time of admission.

Prerequisite	Required by
High-level structured language	All concentrations
MIM 3104 Data Structures	All concentrations
MIM 3140 Concepts of Object-Oriented Design	All concentrations

Course Descriptions

See the respective department sections of this catalog for course descriptions.

Course Requirements

Each area of concentration requires a total of forty-eight quarter hours of course work consisting of required core courses plus electives selected from the approved elective lists. Other courses may be used as electives if approved by petition. Students should petition through their academic adviser. Below is the CAD/CAM Option followed by the Engineering Software Design Option.

CAD/CAM Option

Required Core Courses

			Credits
	MIM 3104	Data Structures	4
	MIM 3128	Database Management Systems	4
Or	COM 3315	Principles of Database Systems	4
	MIM 3300	Manufacturing, Design and Computers	4
	MIM 3325	Robot Mechanics and Control	4
	MIM 3350	Computer-Aided Graphics and Design	4

Subject Area Elective Courses

Students may select courses from the required list of the Engineering Software Design option. Full-time students are encouraged to complete a thesis for twelve quarter hours of credit. In addition, the following courses may be taken as electives. Any other elective outside of this list must be pre-approved by petition.

Design Electives

		Credits
MIM 3000	Mathematical Methods for Mechanical Engineering	4
MIM 3010	Numerical Methods in Mechanical Engineering	4
MIM 3600	Theory of Elasticity	4
MIM 3625	Advanced Dynamics	4
MIM 3630	Vibration Theory and Applications	4
MIM 3675	Advanced Mechanics of Materials	4
MIM 3690	The Finite Element Method	4
MIM 3695	Experimental Techniques in Design	4

Manufacturing Electives

		Credits
ECE 3463	Robot Vision and Sensors	4
ECE 3466	Robotics and Automation Systems	4
MIM 3025	Human Factors Engineering	4
MIM 3217	Engineering Project Management	4
MIM 3305	Manufacturing Methods and Processes	4
MIM 3310	Computer Methods in Manufacturing	4
MIM 3375	Computer-Aided Manufacturing	4
MIM 3400	Basic Probability and Statistics	4
MIM 3416	Statistical Quality Control	4
MIM 3440	Total Quality Control for Engineering	4

		Credits
MIM 3503	Simulation Methodology and Applications	4
MIM 3530	Operations Research 1	4

Intelligent CAD/CAM Electives

		Credits
COM 3112	LISP Lab	2
COM 3315	Principles of Database Systems	4
COM 3360	Adaptive Object-Oriented Software Development	4
COM 3410	Artificial Intelligence Problem Solving	4
COM 3411	Knowledge-Based Systems	4
COM 3420	Knowledge Representation	4
COM 3430	Expert Systems	4
COM 3440	Natural Language Processing	4
COM 3480	Machine Learning and Neural Networks	4
ECE 3221	Linear Systems Analysis	4
MIM 3124	Software Engineering	4
MIM 3129	Expert Systems in Engineering	4
MIM 3130	Machine Intelligence	4
MIM 3131	Machine Learning	4
MIM 3137	Programming Languages for Software Engineering	4
MIM 3140	Concepts of Object-Oriented Design	4
MIM 3141	Component Software Development	4
MIM 3142	Building Virtual Environments	4
MIM 3143	Enterprise Software Development	4

Engineering Software Design Option

The Engineering Software Design concentration is designed for students who have a bachelor's degree in any engineering disciple. Students whose undergraduate major was physics, chemistry, mathematics, or computer science are also welcome to apply.

Required Core Courses

			Credits
	MIM 3107	Operating Systems and Systems Software	4
	MIM 3110	Computer Architecture	4
	MIM 3124	Software Engineering	4
	MIM 3141	Component Software Development	4
	MIM 3152	Software Engineering Project 1	4
	MIM 3153	Software Engineering Project 2	4
Or	MIM 3935	Thesis	8
	MIM 3217	Engineering Project Management	4

Subject Area Elective Courses

Students may select courses from the required list of the CAD/CAM option, except for those that also appear as Engineering Software Design prerequisite courses. In addition, the following courses may be taken as electives:

Software Engineering Electives

		Credits
MIM 3030	Human-Computer Interaction	4
MIM 3125	Software Development and Evolution	4
MIM 3126	Networks and Telecommunications	4
MIM 3128	Database Management Systems	4
MIM 3129	Expert Systems in Engineering	4
MIM 3130	Machine Intelligence	4
MIM 3131	Machine Learning	4
MIM 3133	C++ Object-Oriented Design	4
MIM 3142	Building Virtual Environments	4
MIM 3143	Enterprise Software Development	4
MIM 3300	Manufacturing, Design and Computers	4
MIM 3310	Computer Methods in Manufacturing	4
MIM 3325	Robot Mechanics and Control	4
MIM 3350	Computer-Aided Graphics and Design	4
MIM 3375	Computer-Aided Manufacturing	4
MIM 3503	Simulation Methodology and Applications	4
MIM 3505	Advanced Simulation Analysis	4
ECE 3321	Digital Signal Processing	4
ECE 3463	Robot Vision and Sensors	4
ECE 3466	Robotics and Automation Systems	4
ECE 3556	Special Topics in System Theory	4
COM 3355	Compiler Design	4
COM 3371	Digital Image Processing	4
COM 3420	Knowledge Representation	4
COM 3470	Computer Vision	4

THE DOCTOR OF PHILOSOPHY DEGREE

Students interested in pursuing research related to Computer Systems Engineering beyond the Master of Science level may pursue the Doctor of Philosophy degree under the Interdisciplinary PhD program described elsewhere in this catalog.

Program Advisers

Computer Systems Engineering (CAD/CAM)	Professor Ibrahim Zeid
Computer Systems Engineering (ESD)	Professor Ronald R. Mourant

Department of Electrical and Computer Engineering

The Department of Electrical and Computer Engineering offers graduate programs leading to the degrees of Master of Science in Electrical Engineering, Master of Science (without specification), Doctor of Philosophy in Electrical Engineering, and Doctor of Philosophy in Computer Engineering. The Master of Science degree program may be completed on either a part-time, or a continuous full-time basis. Both PhD degree programs must be completed on a basis consistent with the residence requirements for the degree. The curriculum offers areas of concentration in communications and signal processing; computer engineering; control systems and signal processing; electromagnetics, plasma and optics; electronic circuits and semiconductor devices; and power systems.

Courses offered typically carry four quarter hours of credit although some two quarter hour courses are also offered. Full-time students are responsible for meeting with their faculty advisers early in the program to determine an appropriate sequence of courses. Part-time students should follow the prescribed requirements and confer with their faculty advisers as needed.

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of forty-four quarter hours of graduate courses with a minimum grade point average of 3.000 is required in all programs. Full-time students are required to complete either an eight quarter hour Master of Science Thesis or a four quarter hour Project as part of their program. Research Assistants, Teaching Assistants, and Industrial Fellowship students are required to complete a Master of Science Thesis. Research or Teaching Assistants are not allowed to change their areas of concentration without the approval of their current academic or thesis adviser, the Graduate Affairs Committee, and the Director of the Graduate School of Engineering. Master of Science Thesis or Project is optional for part-time students. For students selecting the thesis option, an Examination Committee shall be formed consisting of the student's thesis adviser and a minimum of two full-time faculty members (or one full-time faculty member and one adviser from industry) with background relevant to the thesis topic. The thesis shall be presented by the student to the Committee and to the Electrical and Computer Engineering (ECE) Department-at-large in the form of a seminar before final approval of the thesis is granted. For students selecting the project option, the student shall select one adviser who will be responsible for the grade, and one other ECE faculty member. The project shall result in a written report and a final examination consisting of a poster session followed by a five-minute presentation. The MS Projects will be presented at one poster session scheduled the Friday before final exam week. The results of the project should be of a quality that is suitable for publication or presentation at a professional conference.

All graduate courses presuppose mastery of the subject matter of a modern ABET accredited

undergraduate curriculum in electrical engineering. Students with a Bachelor of Science degree in other engineering or related science fields and students with a BSEE degree who have not taken graduate academic work for some time may be required to take one or more of the following prerequisite courses to satisfy any deficiencies. These courses carry no credit toward the graduate degree.

Please refer to the *Academic Policies and Procedures* section of this catalog for further detailed information.

Prerequisite Courses

(These courses cannot be used toward the 44 quarter hour degree requirement)

			Credits
ECE	3100	Introduction to Circuits and Systems	4
ECE	3101	Introduction to Electronics	4
ECE	3102	Introduction to Electromagnetic Field Theory	4
ECE	3103	Introduction to Digital Systems Design	4
ECE	3104	Introduction to Communications	4
ECE	3108	Introduction to Signals and Systems	4
ECE	3109	Introduction to Computer Systems	4
ECE	3120	Power Circuit Analysis 1	2
ECE	3130	Electrical Machinery Theory 1	2

Course Requirements

All Master of Science degree candidates must complete a minimum of three courses from the *Master of Science Core Courses* list. In addition, Master of Science degree candidates should select an appropriate number of technical electives in consultation with the student's academic or research adviser. A list of faculty-recommended technical electives within each research area is provided below.

	Full-time with Thesis	Full-time with Project	Part-time Study
Required Core	12 QH	12 QH	12 QH
Technical Electives	24 QH	28 QH	32 QH
MS Thesis or Project	8 QH	4 QH	0 QH
Minimum Quarter Hours Required *	**44 QH**	**44 QH**	**44 QH**

* Exclusive of any prerequisite courses.

Master of Science Core Courses

			Credits
	ECE 3211	Mathematical Methods in Electrical Engineering 1	4
Or	ECE 3231	Mathematical Methods in Electrical Engineering 2	4
	ECE 3221	Linear Systems Analysis	4
	ECE 3241	Applied Probability and Stochastic Processes	4
	ECE 3341	Electromagnetic Theory 1	4
	ECE 3384	Solid State Devices 1	4
	ECE 3391	Computer Architecture	4
	ECE 3652	Fundamentals of Computer Engineering	4

Communications and Signal Processing

Recommended Technical Electives for Communications and Signal Processing

			Credits
ECE	3231	Mathematical Methods in Electrical Engineering 2	4
ECE	3321	Digital Signal Processing	4
ECE	3331	Analog Integrated Circuits	4
ECE	3341	Electromagnetic Theory 1	4
ECE	3344	Electromagnetic Theory 2	4
ECE	3351	Digital Communications	4
ECE	3361	Detection and Estimation Theory	4
ECE	3371	Linear Optimal Control Theory	4
ECE	3381	Classical Control Theory	4
ECE	3391	Computer Architecture	4
ECE	3395	VLSI Design	4
ECE	3398	VLSI Architectures	4
ECE	3473	Parallel Architectures for High Performance Computing	4
ECE	3497	Statistical Signal Processing	4
ECE	3500	Auditory Signal Processing	4
ECE	3505	Digital Image Processing	4
ECE	3508	Modern Spectral Analysis	4
ECE	3511	Network Communications and Performance Engineering	4
ECE	3514	Error Correcting Codes	4
ECE	3526	Nonlinear Systems	4
ECE	3531	Adaptive Signal Processing	4
ECE	3534	Digital Processing of Speech Signals	4
ECE	3537	Multi-User Communications Systems	4
ECE	3540	Digital Control System	4
ECE	3549	Multivariable Control Systems	4
ECE	3552	System Identification and Adaptive Control	4
ECE	3553	Spread Spectrum Communication Systems	4
ECE	3554	Advanced Topics in Communications	4
ECE	3555	Statistical Pattern Recognition and Neural Networks	4
ECE	3556	Special Topics in System Theory	4
ECE	3557	Special Topics in Signal Processing	4
ECE	3558	Digital Filter Banks and Wavelets	4
ECE	3559	Wireless Communications	4
ECE	3563	Radar Systems 1	4
ECE	3566	Radar Systems 2	2
ECE	3567	Network Information Theory	4
ECE	3571	Fourier and Binary Optics	4
ECE	3574	Fourier Optics 2	2
ECE	3579	Optoelectronics and Fiber Optics	2
ECE	3582	Optics for Engineers	4
ECE	3598	Remote Sensing	4
ECE	3635	Antennas and Radiation	4
ECE	3650	Local Area Networks and Inter-Networking	4
ECE	3655	Special Topics in Computer Networks	4
ECE	3656	Mobile and Wireless Networking	4
ECE	3657	Broadband Communications Networks	4
ECE	3694	Special Topics	4
ECE	3893	Special Problems in Electrical Engineering	2
ECE	3896	Special Problems in Electrical Engineering	4

				Credits
	ECE	3860	Master of Science Thesis	8
Or	ECE	3863	Master of Science Project	4

Computer Engineering

Recommended Technical Electives for Computer Engineering

			Credits
ECE	3221	Linear Systems Analysis	4
ECE	3231	Mathematical Methods in Electrical Engineering 2	4
ECE	3311	Software Engineering 1	4
ECE	3314	Software Engineering 2	2
ECE	3321	Digital Signal Processing	4
ECE	3331	Analog Integrated Circuits	4
ECE	3351	Digital Communications	4
ECE	3361	Detection and Estimation Theory	4
ECE	3381	Classical Control Theory	4
ECE	3395	VLSI Design	4
ECE	3398	VLSI Architectures	4
ECE	3401	Digital Systems Design with Hardware Description Languages	4
ECE	3407	Digital Systems Design and Interfacing with Verilog	4
ECE	3463	Robot Vision and Sensors	4
ECE	3466	Robotics and Automation Systems	4
ECE	3469	Fault Tolerant Computers	4
ECE	3473	Parallel Architectures for High Performance Computing	4
ECE	3480	Distributed Systems	4
ECE	3483	Multiprocessor Architecture	4
ECE	3484	Combinatorial Optimization	4
ECE	3485	Digital Hardware Synthesis	4
ECE	3497	Statistical Signal Processing	4
ECE	3511	Network Communications and Performance Engineering	4
ECE	3531	Adaptive Signal Processing	4
ECE	3582	Optics for Engineers	4
ECE	3626	Integrated Circuit Fabrication 1	4
ECE	3650	Local Area Networks and Inter-Networking	4
ECE	3652	Fundamentals of Computer Engineering	4
ECE	3653	Interconnection Networks for Multicomputers	4
ECE	3654	Network Computing	4
ECE	3655	Special Topics in Computer Networks	4
ECE	3656	Mobile and Wireless Networking	4
ECE	3657	Broadband Communications Networks	4
ECE	3694	Special Topics	4
ECE	3893	Special Problems in Electrical Engineering	2
ECE	3896	Special Problems in Electrical Engineering	4
COM	3220	Software Testing, Verification, and Validation	4
COM	3230	Object-Oriented Design	4
COM	3316	Transaction Processing Systems	4
COM	3317	Data Modeling	4
COM	3336	Operating Systems	4
COM	3351	Principles of Programming Languages	4
COM	3355	Compiler Design	4
COM	3356	Optimizing Compilers	4
COM	3364	Object-Oriented Databases	4

			Credits
	COM 3395	Distributed Algorithms	4
	COM 3410	Artificial Intelligence Problem Solving	4
	COM 3470	Computer Vision	4
	COM 3480	Machine Learning and Neural Networks	4
	COM 3515	Internetworking: Principles, Protocols, and Applications	4
	COM 3520	Cryptography and Computer Security	4
	COM 3530	Integrated Services Networks: Design and Evaluation	4
	COM 3560	Distributed Database Systems	4
	COM 3620	Parallel Architecture and Algorithms	4
	COM 3640	Parallel Algorithms	4
	MTH 3212	Elements of Math for Information Systems 2 (Discrete Structures)	2
	ECE 3860	Master of Science Thesis	8
Or	ECE 3863	Master of Science Project	4

Control Systems and Signal Processing

Recommended Technical Electives for Control Systems and Signal Processing

		Credits
ECE 3231	Mathematical Methods in Electrical Engineering 2	4
ECE 3310	Electrical Machinery Theory	4
ECE 3321	Digital Signal Processing	4
ECE 3331	Analog Integrated Circuits	4
ECE 3341	Electromagnetic Theory 1	4
ECE 3361	Detection and Estimation Theory	4
ECE 3371	Linear Optimal Control Theory	4
ECE 3381	Classical Control Theory	4
ECE 3391	Computer Architecture	4
ECE 3395	VLSI Design	4
ECE 3398	VLSI Architectures	4
ECE 3432	Power Systems Operation and Control	4
ECE 3433	Power Electronics	4
ECE 3463	Robot Vision and Sensors	4
ECE 3466	Robotics and Automation System	4
ECE 3473	Parallel Architecture for High Performance Computing	4
ECE 3480	Distributed Systems	4
ECE 3497	Statistical Signal Processing	4
ECE 3500	Auditory Signal Processing	4
ECE 3505	Digital Image Processing	4
ECE 3508	Modern Spectral Analysis	4
ECE 3511	Network Communications and Performance Engineering	4
ECE 3514	Error Correcting Codes	4
ECE 3526	Nonlinear Systems 1	4
ECE 3531	Adaptive Signal Processing	4
ECE 3534	Digital Processing of Speech Signals	4
ECE 3540	Digital Control Systems	4
ECE 3549	Multivariable Control Systems	4
ECE 3552	System Identification and Adaptive Control	4
ECE 3555	Statistical Pattern Recognition and Neural Networks	4
ECE 3558	Digital Filter Banks and Wavelets	4
ECE 3563	Radar Systems 1	4
ECE 3566	Radar Systems 2	2
ECE 3567	Network Information Theory	4

				Credits
	ECE	3574	Fourier Optics 2	2
	ECE	3694	Special Topics	4
	ECE	3893	Special Problems in Electrical Engineering	2
	ECE	3896	Special Problems in Electrical Engineering	4
	MIM	3325	Robot Mechanics and Control	4
	ECE	3860	Master of Science Thesis	8
Or	ECE	3863	Master of Science Project	4

Electromagnetics, Plasma and Optics

Recommended Technicl Electives for Electromagnetics, Plasma and Optics

				Credits
	ECE	3211	Mathematical Methods in Electrical Engineering 1	4
	ECE	3221	Linear Systems Analysis	4
	ECE	3321	Digital Signal Processing	4
	ECE	3344	Electromagnetic Theory 2	4
	ECE	3347	Computational Methods in Electromagnetics	4
	ECE	3384	Solid State Devices 1	4
	ECE	3395	VLSI Design	4
	ECE	3558	Digital Filter Banks and Wavelets	4
	ECE	3563	Radar Systems 1	4
	ECE	3566	Radar Systems 2	2
	ECE	3571	Fourier and Binary Optics	4
	ECE	3574	Fourier Optics 2	2
	ECE	3575	Lasers	4
	ECE	3579	Optoelectronics and Fiber Optics	2
	ECE	3582	Optics for Engineers	4
	ECE	3586	Optical Detection	4
	ECE	3593	Plasma Engineering	4
	ECE	3594	Plasma Theory	4
	ECE	3597	Optical Properties of Matter	4
	ECE	3598	Remote Sensing	4
	ECE	3599	IR Imaging	2
	ECE	3600	Microwave Properties of Materials	4
	ECE	3603	Propagation in Artificial Structures	4
	ECE	3609	Special Topics in Electromagnetics	4
	ECE	3613	Solid State Microwave Circuits	4
	ECE	3626	Integrated Circuits Fabrication 1	4
	ECE	3629	Integrated Circuits Fabrication Processes: Plasma Processing	4
	ECE	3635	Antennas and Radiation	4
	ECE	3638	Microwave Electron Devices	4
	ECE	3641	High Speed/High Frequency Solid State Devices	4
	ECE	3644	Passive Microwave Circuits	4
	ECE	3694	Special Topics	4
	ECE	3893	Special Problems in Electrical Engineering	2
Or	ECE	3896	Special Problems in Electrical Engineering	4
	ECE	3860	Master of Science Thesis	8
Or	ECE	3863	Master of Science Project	4

Electronic Circuits, Semiconductor Devices, and Microfabrication

Recommended Technical Electives for Electronic Circuits, Semiconductor Devices, and Microfabrication

				Credits
	ECE	3211	Mathematical Methods in Electrical Engineering 1	4
	ECE	3221	Linear Systems Analysis	4
	ECE	3231	Mathematical Methods in Electrical Engineering 2	4
	ECE	3321	Digital Signal Processing	4
	ECE	3331	Analog Integrated Circuits	4
	ECE	3341	Electromagnetic Theory 1	4
	ECE	3344	Electromagnetic Theory 2	4
	ECE	3347	Computational Methods in Electromagnetics	4
	ECE	3388	Solid State Devices 2	4
	ECE	3391	Computer Architecture	4
	ECE	3395	VLSI Design	4
	ECE	3398	VLSI Architectures	4
	ECE	3401	Digital System Design with Hardware Description Languages	4
	ECE	3433	Power Electronics	4
	ECE	3582	Optics for Engineers	4
	ECE	3586	Optical Detection	4
	ECE	3597	Optical Properties of Matter	4
	ECE	3610	Electronics of Analog Signal Processing	4
	ECE	3613	Solid State Microwave Circuits	4
	ECE	3626	Integrated Circuit Fabrication 1	4
	ECE	3629	Integrated Circuit Fabrication Processes: Plasma Processing	4
	ECE	3632	Design and Analysis of Digital Integrated Circuits	4
	ECE	3638	Microwave Electron Devices	4
	ECE	3641	High Speed/High Frequency Solid State Devices	4
	ECE	3642	Microelectromechanical Systems	4
	ECE	3644	Passive Microwave Circuits	4
	ECE	3694	Special Topics	4
	ECE	3893	Special Problems in Electrical Engineering	2
	ECE	3896	Special Problems in Electrical Engineering	4
	ECE	3860	Master of Science Thesis	8
Or	ECE	3863	Master of Science Project	4

Power Systems, Power Electronics, and Motion Control

Recommended Technical Electives for Power Systems, Power Electronics, and Motion Control

			Credits
ECE	3304	Motion Control with DC Drives	2
ECE	3307	Motion Control with AC Drives	2
ECE	3310	Electrical Machinery Theory	4
ECE	3321	Digital Signal Processing	4
ECE	3331	Analog Integrated Circuits	4
ECE	3341	Electromagnetic Theory 1	4
ECE	3371	Linear Optimal Control Theory	4
ECE	3381	Classical Control Theory	4
ECE	3412	Power Systems Planning	4
ECE	3417	Analysis of Equipment Failure	2
ECE	3429	Electric Power Transmission	4
ECE	3432	Power Systems Operation and Control	4

				Credits
	ECE	3433	Power Electronics	4
	ECE	3526	Nonlinear Systems	4
	ECE	3540	Digital Control Systems	4
	ECE	3549	Multivariable Control Systems	4
	ECE	3552	System Identification and Adaptive Control	4
	ECE	3632	Design and Analysis of Digital Integrated Circuits	4
	ECE	3694	Special Topics	4
	ECE	3893	Special Problems in Electrical Engineering	2
	ECE	3896	Special Problems in Electrical Engineering	4
	MIM	3215	Engineering Economy	4
	ECE	3860	Master of Science Thesis	8
Or	ECE	3863	Master of Science Project	4

THE DOCTOR OF PHILOSOPHY DEGREE

Beginning in the Fall Quarter 2001, the Department of Electrical and Computer Engineering will offer two doctoral degree programs, one in Electrical Engineering and one in Computer Engineering.

Doctoral Degree Program in Electrical Engineering

Course Requirements

A program of study is determined by the candidate and the Dissertation Committee. A typical program consists of thirty-two quarter hours of course work beyond the Master of Science degree. The PhD program, however, must consist of at least twenty-four quarter hours of course work. The exact nature of the program of study will vary among candidates depending on the dissertation subject area and the candidate's preparation. The program will include **one minor area of study** consisting of at least twelve quarter hours of course work beyond the Master of Science degree in an area other than that in which the candidate is concentrating. The minor may be in another discipline within electrical and computer engineering or the minor area may be in another relevant technical or scientific discipline. The candidate must achieve an overall minimum 3.000 QPA and a 3.000 QPA in the minor area.

Doctoral Degree Program in Computer Engineering

Course Requirements

A program of study is determined by the candidate and the Dissertation Adviser. A typical program consists of thirty-two quarter hours of course work beyond the Master of Science degree. The PhD program, however, must contain at least twenty-four quarter hours of course work. The exact nature of the program will vary among candidates depending on the dissertation subject area and the candidate's preparation. The program will include a minimum of eight quarter hours of course work beyond the Master of Science degree in non-Computer Engineering courses. The candidate must achieve an overall minimum 3.000 QPA and a 3.000 QPA in the non-Computer Engineering area.

REQUIREMENTS APPLICABLE TO THE DOCTORAL PROGRAMS IN ELECTRICAL ENGINEERING AND IN COMPUTER ENGINEERING

Qualifying Examination and Degree Candidacy

The PhD qualifying examination is the examination for admission to the doctoral programs in Electrical Engineering and in Computer Engineering. The examination has the dual purpose of serving as an indicator of the student's capability for successful completion of the PhD in Electrical Engineering or the PhD in Computer Engineering and serving as a guide to the student's adviser in developing a suitable plan of study tailored to the individual needs of the candidate. A student who has received approval to take the qualifying examination is considered a predoctoral student until such time as he or she passes the examination. Upon successful completion of the qualifying examination the student becomes a PhD candidate.

The PhD Qualifying Examination in both programs consists of a written examination in the student's major area. This examination must be taken by all predoctoral students with a Master's degree or equivalent in the spring quarter of the first year. Students will be tested on graduate course material as specified by the faculty in the chosen area. A student who fails the written examination will be permitted to retake the examination only once.

Please note the following information:

1. Students admitted to the PhD program as predoctoral candidates who already have a Master's Degree in Electrical or Computer Engineering must take the PhD qualifying examination in their first academic year. Those students are expected to work towards completion of the doctoral program without obtaining a second Master's Degree. There are no exceptions to this policy.
2. All graduate students holding research or teaching assistantship positions cannot change their areas of concentration without the approval from their current academic or thesis advisers, the Graduate Committee, and the Director of the Graduate School of Engineering

Dissertation

Within one academic quarter after passing the PhD qualifying examination, the doctoral candidate must form a Dissertation Committee and petition the Graduate Committee for approval of this Committee. A Dissertation Committee consists of the adviser and two full-time faculty members with background relevant to the thesis topic. The Chair of the Dissertation Committee must be a faculty member of the ECE Department. The Committee may also include a person from industry or another university.

The Dissertation Committee for the PhD student in Electrical Engineering, and the Dissertation Adviser for the PhD student in Computer Engineering, is charged with designing an appropriate course work program that prepares the student to be a successful doctoral-level engineer. A Dissertation Adviser directs the candidate's dissertation research. The Dissertation Committee will approve the dissertation in final form.

Advanced Seminar

Starting with predoctoral students admitted in the Fall 1999 Quarter, the following requirements are applicable as part of the PhD program. Each student must register for and pass ECE 3890, Advanced Seminar, in the area of their PhD dissertation. The topic and material for the seminar assignment for each student will be selected jointly by the seminar coordinator and the student's thesis adviser. The grade for ECE 3890, Advanced Seminar, is either Satisfactory (S) or Unsatisfactory (U).

Residence Requirement

One year of full-time graduate work or two consecutive years of part-time graduate work satisfy the

residence requirement. In the latter case, the student's adviser must approve a detailed time schedule in order to give evidence that at least half of the time is being devoted to the requirements of the graduate school.

ECE 3880 Doctoral Thesis and ECE 3799 Thesis Continuation Requirements

Upon successful completion of the PhD qualifying examination and the majority of required course work, the student is also required to register for three consecutive quarters for ECE 3880 Doctoral Thesis. Upon completion of this sequence, the student is required to register for ECE 3799 PhD Thesis Continuation in every quarter until the dissertation has been completed. Students may not register for continuation until the three-quarter sequence has been fulfilled.

Registration Requirements for Graduate Assistants

Predoctoral and doctoral students, who hold research, teaching, or tuition assistantship positions, are required to register for eight quarter hours of course work per quarter, including the Summer Quarter. The assistantship is contingent upon registering for the eight quarter hours. ECE 3885, Doctoral Research (4QH) and ECE 3886, Doctoral Research (8QH) have been added to the list of courses available to students who have passed the qualifying examination. These additional courses can be used to meet the eight quarter registration requirement. Grades for ECE 3885 and ECE 3886 are Satisfactory (S) or Unsatisfactory (U) at the completion of the PhD dissertation. In the interim the grade of IP (In Progress) will be given. *ECE 3885 and ECE 3886 Doctoral research credits do not count towards satisfying the minimum credit hours for the PhD degree.*

Comprehensive Examination

Within three years of establishment of degree candidacy, the student will be required to demonstrate by means of a comprehensive examination, a subject matter knowledge satisfactory for the award of the degree.

The comprehensive examination is an oral examination open to the Department of Electrical and Computer Engineering faculty (assistant professor and above in rank) and administered by the student's Dissertation Committee. Departmental faculty will be informed of the examination via a departmental notice at least one week prior to the examination. Normally the examination will be given at the time the Dissertation Proposal is submitted to the Dissertation Committee for approval. As part of this examination the Dissertation Committee will review the student's doctoral program and his/her performance in graduate courses, as well as examine the student on subject matter related to graduate studies and dissertation area.

Final Oral Examination

The final oral examination will include the subject matter of the doctoral dissertation and significant developments in the field of the dissertation work. Other related fields may be included if recommended by the examining committee.

FACULTY

Fabrizio Lombardi, PhD, Chairman and ITC Professor

Professors

Buus, Soren, PhD, Northeastern University; psychoacoustics, signal processing, microprocessors

Chan, Chung, PhD, University of Iowa; plasmas, electromagnetics

Devaney, Anthony, PhD, University of Rochester; tomography, electromagnetic wave propagation, inverse scattering

Grabel, Arvin, ScD, New York University; integrated circuits, electronics

Lombardi, Fabrizio, PhD, University College, London England; digital systems fault tolerant

computing, CAD, manufacturing of ICs, configurable computing

McKnight, Stephen, PhD, University of Maryland; semiconductor devices and materials, electro-optics, electromagnetics

Mulukutla, Sarma, PhD, University of Colorado; power systems, electrical machinery, electromagnetic theory and its applications to electrical machines

Prasad, Sheila, PhD, Harvard University; microwave solid state devices and circuits, optoelectronics

Rappaport, Carey, Sc.D., Massachusetts Institute of Technology; electromagnetics, microwaves

Schetzen, Martin, Sc.D., Massachusetts Institute of Technology; systems theory, control systems, theory of nonlinear systems

Serafim, Philip, Sc.D., Massachusetts Institute of Technology; electromagnetics, remote sensing

Silevitch, Michael, PhD, Northeastern University; plasma theory, applications of plasma theory to auroral phenomena

Vittoria, Carmine, PhD, Yale University; electromagnetics, magnetic materials, microwave circuits

Associate Professors

Brady, David, PhD, Princeton University; digital communications, multi-user communications

Brooks, Dana, PhD, Northeastern University; digital signal processing

DiMarzio, Charles, PhD, Northeastern University; optics, biomedical imaging, subsurface sensing and imaging

Hopwood, Jeffrey, PhD, Michigan State; plasma processing, IC fabrication

Ingle, Vinay, PhD, Rensselaer Polytechnic Institute; signal processing, image processing

Kaeli, David, PhD, Rutgers University; computer architecture, software engineering

Kokar, Mieczyslaw, PhD, Technical University of Wroclaw; artificial intelligence, operating systems

Leeser, Miriam, PhD, Cambridge University; CAD, VLSI design, rapid system prototyping

Lehman, Bradley, PhD, Georgia Institute of Technology; control systems, power systems

Lev-Ari, Hanoch, PhD, Stanford University; digital signal processing, adaptive filtering

Manolakos, Elias, PhD, University of Southern California; computer engineering, VLSI design, signal processing algorithms

McGruer, Nicol, PhD, Michigan State University; solid state devices, IC fabrication

Miller, Eric, PhD, Massachusetts Institute of Technology; signal and image processing

Salehi, Masoud, PhD, Stanford University; information theory, coding

Shafai, Bahram, PhD, George Washington University; control systems, digital signal processing

Stankovic, Aleksander, PhD, Massachusetts Institute of Technology; power systems, power electronics, control systems

Tadmor, Gilead, PhD, Weizmann Institute, Israel; control systems

Assistant Professors

Basagni, Stefano, PhD, Universita degli Studi di Milano and University of Texas; distributed algorithms, wireless networking

Dy, Jennifer, PhD, Purdue University; image processing, robotics

Kirchner, Frank, PhD, University of Bonn; software development, biomemetic autonomous robots, control

Kim, Yong-Bin, PhD, Colorado State University; VLSI, computer-aided design electronics

McDonald, A. Bruce, PhD, University of Pittsburgh; wireless telecommunications, networking

Meleis, Waleed, PhD, University of Michigan: computer engineering, computer architecture, performance optimization

Meyer, Fred, PhD, University of Massachusetts, Amherst; computer engineering

Program Advisers

An adviser will be assigned to you upon admission to the Graduate School. If you are unable to reach your adviser you may call the ECE Department Graduate Program Coordinator at 617.373.5281.

Each course description includes information on the expected quarter in which classes are usually offered. The quarters listed are presented here for planning purposes; however, the Graduate School of Engineering cannot guarantee that all courses will be offered. Students must refer to the Graduate School of Engineering Quarterly Course Offering booklets to determine what courses are actually offered in any given quarter.

ECE 3100 Introduction to Circuits and Systems (4QH)
As Announced

The circuit elements (R, L and C) are introduced. Kirchoff's Laws, Tellegan and Thevenin's Theorem. Mesh and nodal analysis. Development of system function approach, Laplace and Fourier transform theory applied to circuit analysis. Sinusoidal steady-state, n-port network theory and power and energy concepts. *Prerequisite: Admission to Graduate School.*

ECE 3101 Introduction to Electronics (4QH)
As Announced

Characteristics of the theoretical physical junction. The Ebers-Moll model for bipolar junction transistors, characteristics of bipolar and field-effect devices, basic digital inverters and logic gates and various logic families. Use of transistors in the design of analog circuits. Biasing, linearized incremental models, load lines, signal flowgraphs, frequency response and gain calculation for single and cascaded stages. *Prerequisite: ECE 3100 or equivalent.*

ECE 3102 Introduction to Electromagnetic Field Theory (4QH)
As Announced

Definition of scalar and vector fields; vector calculus; concepts of gradient, divergence, curl and the "del" operator; free-space electrostatics; the generalization of the Maxwell equations to the case of time-varying fields; Faraday induction law, wave equations and the place wave solution. *Prerequisite: ECE 3100 or equivalent.*

ECE 3103 Introduction to Digital Systems Design (4QH)
As Announced

Basic components of digital systems and methods for their analysis and design, combinational and sequential circuits, integrated circuit logic families and functional building blocks, registers, counters, decoders, multiplexers and memories. Data representation and coding techniques. Central processor alternatives; instruction formats, addressing modes, bus structures, arithmetic units, timing analysis and stacks. Algorithms for arithmetic operations with various data representations. *Prerequisite: Admission to Graduate School.*

CE 3104 Introduction to Communications (4QH)
As Announced

Review of system theory, convolution, Fourier series, Fourier integral, signal analysis, Fourier methods, correlation functions, density functions, power spectra, amplitude modulation, frequency modulation, phase modulation, sampling theory and digital modulation techniques. *Prerequisite: ECE 3108 or equivalent.*

ECE 3108 Introduction to Signals and Systems (4QH)
As Announced

Description and analysis of continuous and discrete time signals and systems. Time domain analysis of linear, time-invariant (LTI) systems. Frequency domain analysis of signals and LTI systems. Laplace and z-transforms. State space descriptions of continuous and discrete time systems. *Prerequisite: ECE 3100 or equivalent.*

ECE 3109 Introduction to Computer Systems (4QH)
As Announced

The course will comprise two central topics: 1) data structures and algorithms, and 2) computer architecture and organization. The purpose of this course is to provide a non-electrical engineering student with sufficient background to be able to enter graduate-level Computer Engineering courses. Data structures, including stacks, lists, heaps, and other abstract data types will be covered. Algorithm complexity will be covered for searches, sorts, parses, and popular algorithms. Programming projects will involve implementing many of these data structures and algorithms. All programming will be done in C or C++. The computer architecture and organization portion of this course will cover assembly language, instruction sets, memory, I/O, and the basic logic building blocks used to construct such systems. System software will also be discussed, including compilers, operating systems, and I/O management. *Prerequisite: Working knowledge of C programming language.*

ECE 3120 Power Circuit Analysis 1 (2QH)
As Announced

Fundamental concepts of single-phase and poly-phase power systems; definitions of terms; use of per unit quantities; equivalent circuits of symmetrical 3-phase systems; introduction of symmetrical components; short circuits on systems with a single power source. *Prerequisite: BSEE or ECE 3100 and ECE 3102.*

ECE 3130 Electrical Machinery Theory 1 (2QH)
As Announced

Review of magnetic circuit concepts and electromechanical energy-conversion principles; steady-state analysis of transformers, synchronous machines, and induction machines. *Prerequisite: BSEE or ECE 3100 and ECE 3102.*

ECE 3211 Mathematical Methods Electrical Engineering 1 (4QH)
Fall Quarter

Fundamental Algebraic Concepts; Sets, functions, relations, operations; Algebraic Structures; group, rings, fields, homomorphisms, polynomials; Vector Spaces and Linear Operators; representations, matrices and linear algebraic equations, orthogonality, equivalence and similarity

transformations, eigenvalues and eigenvectors, canonical forms, functions of a square matrix, quadratic forms and congruence transformations, orthogonal transformations; Introduction to Polynomial Matrices; Applications to Communications and Control Theory. *Prerequisite: Admission to Graduate School.*

ECE 3221 Linear Systems Analysis (4QH)
Fall and Winter Quarters

Introduction to the state variable theory of continuous and discrete linear systems. Standard canonical representations, the concept of state and the representation of interconnected systems, linear spaces, the state equations and their solution, stability, introduction to the general control problem in terms of controllability and observability. *Prerequisite: ECE 3211, ECE 3108 or equivalent.*

ECE 3231 Mathematical Methods in Electrical Engineering 2 (4QH)
Fall Quarter

Complex variable theory; analytic functions and Cauchy-Riemann equations, complex integration and Cauchy integral formula, Taylor and Laurent Series, the residue theorem, conformal mapping; Laplace transform and its applications, problems in partial differential equations; generalized Fourier Series and Green's functions; general integral transforms; Sturm-Liouville, Fourier, Hankel, Legendre and other integral transforms. *Prerequisite: Admission to Graduate School.*

ECE 3241 Applied Probability and Stochastic Processes (4QH)
Fall and Winter Quarters

Introductory probability, sample space and random variables, examples of discrete and continuous probability distribution functions, averages, moments and characteristic function, multivariate distributions, change of variables and functions of variables, central limit theorem, description of stochastic vectors. General concepts of stochastic processes, stationarity and ergodicity, stochastic continuity and differentiation, the Gaussian process, linear systems with stochastic inputs, correlation functions and power spectra, matched filtering, stochastic orthogonality and linear mean-square estimation filtering and prediction. *Prerequisite: ECE 3108 or equivalent.*

ECE 3301 Power Circuit Analysis (4QH)
As Announced

A continuation of ECE 3120 Power Circuit Analysis 1. Symmetrical components are applied to the solution of power systems under unbalanced fault conditions - phase to ground, two phase to ground, phase to phase, open conductor. Formulation of the Impedance Matrix and its use in the solution of short circuits by computer methods is covered. Economic Dispatch methods, the solution of the Power Flow Problem using Newton-Raphson with the Stott-Alsac approximation, and solution of the Transient Stability Problem with the Equal-Area Method for single machines and computer solution of multi-machine power systems is included. *Prerequisite: ECE 3120.*

ECE 3304 Motion Control with DC Drives (2QH)
As Announced

DC motor dynamics and transfer function. Single phase and three phase rectifier circuits with motor loads. Feedback control, chopper controlled DC motors, examples from industry and design considerations. *Prerequisite: BSEE or ECE 3100 and ECE 3101, or equivalent.*

ECE 3307 Motion Control with AC Drives (2QH)
As Announced

Induction and synchronous motor equivalent circuits and characteristics - operation of inverters - pulse-width modulation, voltage-source inverters, current-source inverters, load-commutated inverters and cycloconverters - feedback control - applications and design considerations. *Prerequisite: ECE 3310.*

ECE 3310 Electrical Machinery Theory (4QH)
As Announced

Mathematical description of a synchronous machine; per-unit representation; steady-state theory and transient performance; flux distribution and saturation in synchronous machines. Review of transient behavior of synchronous machines; stability studies and excitation systems; synchronous machine modeling; generator protection; trends in development of large generators. *Prerequisite: ECE 3130.*

ECE 3311 Software Engineering 1 (4QH)
Fall Quarter

This course presents two main topics. First, traditional methods in Software Engineering are presented. This includes the various development models, requirements, specification, design, prototyping, implementation, test, and maintenance. The second topic discusses object-oriented design principles. Concepts such as encapsulation, inheritance, and polymorphism are discussed. A software project will be assigned that will contrast the differences between function-oriented and object-oriented design. *Prerequisite: Working knowledge of the C programming language.*

ECE 3314 Software Engineering 2 (2QH)
As Announced

Focus turns away from the general issues of the first two courses in this sequence and toward a very specific issue, modular design of software. Issues of stepwise-refinement and top-down design are explored in depth and organizational/data-flow issues are considered. *Prerequisite: ECE 3311.*

ECE 3321 Digital Signal Processing (4QH)
Fall Quarter

Theory and practice of modern signal processing techniques. Characteristics of discrete signals and systems, sampling and A/D conversion; the z-transform, the Fourier transform and the discrete Fourier transform; fast Fourier transform algorithms; design techniques for IIR and FIR digital filters; multirate digital filters; quantization effects in digital signal processing. *Prerequisite: ECE 3221.*

ECE 3331 Analog Integrated Circuits (4QH)
Fall Quarter

Active transistor circuits and systems are treated with emphasis on modern integrated circuit architectures. Bipolar and field-effect (NMOS and CMOS) implementations of analog circuits are presented. Characteristics and behaviors of analog I.C. structures are explored through the study of circuits such as, operational amplifiers, instrumentation amplifiers, voltage comparators, various types of filter

configuration and integrators as well as multipliers and logarithmic amplifiers. Features covered include linearity, dynamic range, slew-rate limiting and speed and gain bandwidth trade-offs. The role of feedback in stabilizing, linearizing and otherwise enhancing the performance of analog circuits is treated in detail. Noise limitations on circuit performance are explored. Noise models of devices and circuits are developed, leading to the prediction of system noise performance and techniques for optimizing signal-to-noise ratios. *Prerequisite: ECE 3101 or equivalent.*

ECE 3341 Electromagnetic Theory 1 (4QH)
Fall Quarter

Emphasis is on the fundamental equations, their physical meaning, principal mathematical techniques and important engineering applications. Sources of the EM field; Lorentz force equation; integral form of Maxwell's equations and point relations (differential equations and boundary conditions); electromagnetic energy and power; propagation of plane waves in homogeneous media; reflection and transmission; scalar and vector potentials; solutions in the absence of boundaries for static and dynamic problems, with or without symmetry; solutions to boundary value problems; Green's functions; transmission lines, rectangular waveguides, and resonators; dielectric slab guide. *Prerequisite: ECE 3102 or equivalent.*

ECE 3344 Electromagnetic Theory 2 (4QH)
Winter and Spring Quarters

Examination of important electrodynamic applications by the use of advanced mathematical techniques. General theory of waveguides and resonators with application to the cylindrical geometry; Dielectric rod waveguide; optical fibers; radiation: linear antennas; loop antenna; linear arrays; ray optics; scattering and diffraction of waves for planar, cylindrical and spherical geometries; effects of random media. *Prerequisite: ECE 3341.*

ECE 3347 Computational Methods in Electromagnetics (4QH)
As Announced

Solutions to problems in electromagnetics are presented using a wide variety of numerical and computational methods. Finite difference approximations of partial differential equations and the Finite Difference Time Domain method of simulating electromagnetic wave propagation and scattering will be discussed in detail. Moment methods will be used to solve the integral equations related to currents and charges on wire structures. Finite element and higher-order finite difference methods will be used to solve problems in electrostatics and wave propagation. Efficient matrix methods, relaxation methods, the conjugate gradient technique, and multidimensional Newton's method will be presented in the context of electromagnetic field simulation. *Prerequisite: ECE 3341.*

ECE 3351 Digital Communications (4QH)
As Announced

The theoretical and practical aspects of digital communications in the presence of channel distortion and additive noise. Topics covered include the basic binary and M-ary modulation techniques, namely, PSK, PAM, FSK, orthogonal and biorthogonal signals, and their performance in an additive Gaussian noise channel; signal waveforms constructed from binary block and convolutional codes; hard-decision decoding and soft-decision decoding of coded signal waveforms; performance of coded waveforms in an additive white Gaussian noise channel; trellis-coded modulation. *Prerequisites: ECE 3241 and ECE 3104 or equivalent.*

ECE 3361 Detection and Estimation Theory (4QH)
Winter Quarter

The classical theory of detection and estimation of signals in noise with emphasis on implementation of the theory. Particular topics include hypothesis testing criteria; coherent detection of M-ary signals; diversity receiver; calculation of error probabilities. Detection in colored noise; parameter estimation using Bayes, maximum-likelihood, a maximum land posteriori criteria; applications of the theory to digital communications and radar. *Prerequisite: ECE 3241.*

ECE 3371 Linear Optimal Control Theory (4QH)
As Announced

State-space, time-domain techniques for analyzing and designing linear optimal control systems will be explored. The goal is to introduce basic concepts of dynamic optimization and then to apply them to problems of short and long terms optimal control, stabilization, state estimation and filtering, stochastic and worst-case robust control. Emphasis will be placed on linear quadratic optimization. *Prerequisites: ECE 3221 and ECE 3241.*

ECE 3381 Classical Control Theory (4QH)
As Announced

Basic systems modeling; steady state and transient response analysis. Introduction to root-locus plots, Bode plots, Nyquist plots, and Nichols chart. The design of first order cascade and feedback compensators using the above plots. Pole-zero synthesis techniques and design techniques for the optimal linear regulator problem. *Prerequisite: ECE 3108 or equivalent.*

ECE 3384 Solid State Devices 1 (4QH)
Fall Quarter

Crystal structure, quantum theory, energy bands, semiconductor statistics, generation and recombination, carrier transport phenomena, p-n junction theory, charge storage and diode transients. *Prerequisite: ECE 3101 or equivalent.*

ECE 3388 Solid State Devices 2 (4QH)
As Announced

Bipolar junction transistors, Gummel-Poon model, metal-semiconductor contacts, methods of measurement of barrier height, MIS diode, C-V measurement to evaluate the interface-trapped charges: MOSFET device and structure, charge control model, device scaling, short channel effects, submicron structures; CMOS. *Prerequisite: ECE 3384.*

ECE 3391 Computer Architecture (4QH)
Winter Quarter

This course presents many of the issues involved in the design and analysis of new and evolving computer architectures. Topics include all aspects of the system including the microprocessor, memory, I/O and networking. The course emphasizes the connection between architecture and the underlying software which drives the architecture. Focus areas include: pipelining, superscalar, out of order execution and completion, dataflow, caching, prefetching, virtual memory, RAID and ATM switching. Performance

analysis is another fundamental theme of this course. A project is assigned that involves the creation of a trace-driven simulation model to study the performance of various hardware or software architectural features. The course will also provide a survey of the current state-of-art in processor architectures and will provide additional readings from recent research in the field. *Prerequisite: Working knowledge of C programming language.*

ECE 3395 VLSI Design (4QH)
As Announced

This course covers all aspects of VLSI design and engineering including: VLSI design methodology; MOS transistors and circuits; use CAD tools to create, extract, simulate and evaluate physical layouts; CMOS fabrication process; evaluation and optimization of circuit area, power consumption and propagation delay; use CAD tools to design CMOS systems with standard cells; design and evaluate system clocking; study the characteristics and limitations of CAD tools such as simulation, placement and routing; study VLSI testing, fault models, test vector generation and design for testability; design projects going through a complete VLSI design cycle; a research project targeting a specific area of VLSI engineering. *Prerequisites: ECE 3101 and ECE 3103 or equivalent.*

ECE 3398 VLSI Architectures (4QH)
As Announced

This course augments the physical level VLSI design knowledge built in ECE 3395 by studying how to take advantage of VLSI technologies. Two architectural level design projects provide students with the opportunity to go through the design process of VLSI architectures. Prior project examples include the design and evaluation of FPGAs, application specific processors, and microprocessors. Performance and cost tradeoffs and decision making are specifically emphasized in these projects. Lectures provide theories and discussions to support these two design projects which include a brief review of VLSI design methodology; pipelining and parallel processing in VLSI processors; interconnection between VLSI processing units; VLSI oriented algorithms and applications; VLSI architecture synthesis; special VLSI architectures such as synchronous and asynchronous processor arrays and massively parallel fine-grained processor arrays; reconfigurable VLSI architectures. *Prerequisite: ECE 3395.*

ECE 3401 Digital Systems Design with Hardware Description Languages (4QH)
As Announced

This course covers design, simulation, modeling, and implementation of complex digital systems using high level computer hardware description languages (HDL). It begins with a description of digital system design hierarchy, and abstraction. Next a brief overview of available design tools and simulation programs will be given. HDLs, with emphasis on VHDL and AHPL will then be introduced. Using these languages for design and verification of digital systems at different levels of abstraction will be studied. Students will use VHDL software for design and simulation of large digital circuits. Silicon compilation, computer-aided design and automatic generation of hardware will also be addressed. *Prerequisite: ECE 3391.*

ECE 3407 Digital System Design and Interfacing with Verilog (4QH)
As Announced

The course covers automated design and synthesis of digital systems with the standard Verilog hardware description language emphasizing on CPU structures and interfacing. We will show how Verilog can be used for simulation, synthesis and test of digital systems. Hardware description using predefined parts, using the bussing structure of a system or using a mapping of inputs to outputs will be discussed. After a complete presentation of the Verilog language, synthesizability concepts and templates for logic unit, memory unit, and state machine synthesis will be presented. The course continues by using Verilog in a complete design and description of a CPU, its peripheral devices, and generation of a complete CPU board. In the discussion of the CPU, various forms of controllers, stack, and addressing modes will be discussed and corresponding Verilog code will be presented. Cashing and alternatives in cache hardware and replacement algorithms will be discussed by presenting their Verilog code. Bus arbitration and multiple use of system busses will be demonstrated by presenting a DMA system for the CPU and interfacing it with the CPU. All presentations will lead to a complete Verilog code for a CPU board. A test-bench in Verilog will be developed that will read an assembly code, apply it to the CPU board and monitor flow of data in system components and busses. *Prerequisite: Admission to Graduate School.*

ECE 3412 Power Systems Planning (4QH)
As Announced

Engineering and economic considerations underlying the planning and development of modern interconnected power systems. Consideration of overall planning strategies involved in economic comparison of alternative development schemes. *Prerequisite: ECE 3120.*

ECE 3417 Analysis of Equipment Failure (2QH)
As Announced

Predicting the failure rate for equipment with little or no failure history will be illustrated using Bayesian Analysis which combines the meager failure data with a model for the failure process, to produce results much better than that obtained from Classical Probability Analysis. All results will be shown as probability histograms so that the uncertainty is explicit thus providing the decision maker with the actual odds of either making or losing money on a proposed availability improvement program. *Prerequisite: Admission to Graduate School.*

ECE 3429 Electric Power Transmission (4QH)
As Announced

Elements in the design of AC overhead transmission lines; thermal limitation, series and shunt compensation, environmental effects; consideration of transposition, induced effects, and insulation level. Underground alternatives to overhead lines. Elements of distribution. Fundamental concepts of high voltage DC power transmission; rectifier and inverter performance; regulation; protection; reactive power and filter requirements; practical arrangement of DC lines; the impact of a DC line on overall power system operations. *Prerequisite: ECE 3303.*

ECE 3432 Power Systems Operation and Control (4QH)
As Announced

The first part of the course covers the classical study of steady states in power systems and the solution of some voltage stability problems associated with them of very recent vintage. The goal is to present problem formulations and solutions to problems of load flow with several modifications, namely frequency deviations and voltage-sensitive loads. The second part of the course covers modeling, analysis and controller design for electromechanical transients in power systems (load variations, frequency, and power transmission dynamics). *Prerequisite: ECE 3241.*

ECE 3433 Power Electronics (4QH)
As Announced

The first part of the course emphasizes understanding and modeling of power electronic circuits, and provides background for engineering evaluation of power converters. The second part of the course covers dynamics and control of this class of systems, enabling students to design controllers for a variety of power converters and motion control systems. The course is designed for students with primary interest in power conditioning, control applications and electronic circuits, but it may prove useful for designers of high-performance computers and other electronic systems in which the role of power supplies has to be adequately assessed. *Prerequisite: Undergraduate course in Control Systems or ECE 3381.*

ECE 3463 Robot Vision and Sensors (4QH)
As Announced

Methods of acquisition, representation and processing of real world information for robot control. A major portion of the course focuses on the different aspects of robot vision. Topics include: projection, lens distortion, image noise reduction, texture, edge-based systems, region-based systems, Hough space, matched filtering, object modeling, stereo vision, motion, and optical flow. Robot sensors covers a variety of sensor types including force/torque, proximity, and tactile sensors. *Prerequisite: ECE 3466.*

ECE 3466 Robotics and Automation Systems (4QH)
As Announced

Methods of operation of general purpose and industrial manipulator systems; Kinematic and dynamic models of mechanical arms; joint solutions and motion characteristics; trajectory planning; arm control through coordinate transformations; classical feedback methods and modern closed-loop control techniques; real-time control of robotic systems. *Prerequisite: ECE 3221.*

ECE 3469 Fault-Tolerant Computers (4QH)
As Announced

The course objective is to overview fault-tolerant computing, the design and evaluation of dependable systems, and also to provide a base for research in fault-tolerant systems. Quantitative evaluation and modeling provide the foundation for study of fault avoidance, fault detection, and fault removal from the component level to the system level. Contemporary and historical architectures are analyzed. Software evaluation tools are available for the class to explore fault-tolerant design spaces. *Prerequisite: ECE 3391.*

ECE 3473 Parallel Architectures for High Performance Computing (4QH)
Spring Quarter

This course is concerned about how the concurrency that is inherently present in numerical computations can be exploited for high performance in multi-computer networks and application-specific processor architectures. We start from the basics by introducing: different models of parallel computation, practical network architectures (ring, mesh, hypercube), message routing mechanisms, coordination and communication primitives (one-to-all, all-to-all, broadcasting), parallel and distributed systems performance and scalability evaluation methods. Then we discuss how a sequential nested-loops algorithm can be transformed systematically into a parallel computational structure, so that it can be realized either in hardware (using a domain-specific architecture) or in software (using a network of distributed general purpose computers). Numerical algorithms are used to highlight the key issues involved in this mapping. High performance scalable parallelization strategies for computationally intensive operations, such as dense and sparse linear system solvers, multidimensional data transforms, neural network simulators etc., often encountered in scientific, and multimedia applications are among the case studies analyzed in detail.

ECE 3477 Testing and Design for Testability (4QH)
As Announced

This course encompasses the theoretical and practical aspects of digital systems testing and the design of easily testable circuits. Major topics for the course include defect and fault models, test generation for combinational and sequential circuits, testing measures and costs, functional and parametric test methods, design for testability, built-in self test, and concurrent testing. The objective of the course is to provide the foundations for developing test methods for digital systems and to provide the techniques necessary to practice design for testability. *Prerequisite: ECE 3395.*

ECE 3480 Distributed Systems (4QH)
As Announced

This course covers fundamentals of distributed systems, distributed computing models, client-server computing, remote procedure calls, distributed file and directory services, distributed systems design and implementation issues, reliability and availability, security, overview of computer networks, and case studies in distributed systems. *Prerequisite: Undergraduate course in Operating Systems.*

ECE 3483 Multiprocessor Architectures (4QH)
As Announced

This course presents the issues related to designing and programming tightly-coupled shared-memory multiprocessor systems. The course will cover the issues of memory structure, snoopy and directory-based caching, memory consistency protocols, cache coherency protocols, processor interconnect strategies, and multiprocessor scalability. Issues related to program execution of real applications on a multiprocessor system will be covered, including synchronization primitives, task scheduling, and memory allocation. *Prerequisite: Introductory course in computer architecture.*

ECE 3484 Combinatorial Optimization (4QH)
Winter Quarter

An introduction to combinatorial optimization, an emerging field that combines techniques from applied mathematics, operations research and computer science to solve optimization problems over discrete structures. Emphasizes problems that arise in the areas of Electrical and Computer Engineering, including (but not limited to) VLSI, computer aided design, parallel computing, computer architecture, and high performance compiling. Covers the foundations of algorithm analysis, including asymptotic notation and complexity theory, and a range of optimization techniques, including divide and conquer, local optimization, dynamic programming, branch and bound, simulated annealing, genetic algorithms, approximation algorithms, integer and linear programming, matroid theory, and greedy algorithms. Considers the efficient generation of optimal solutions, the development and evaluation of heuristics, and the computation of tight upper and lower bounds. *Prerequisite: Admission to the Graduate School.*

ECE 3485 Digital Hardware Synthesis (4QH)
As Announced

Techniques and tools for the automatic synthesis of digital systems. The course will focus on algorithms for translating a high level specification into an implementation. Topics covered will include a brief introduction to hardware description languages (HDL), automatic translation of the HDL to an intermediate format, architectural synthesis of the register transfer level implementation, automatic state machine synthesis and logic synthesis. Students will complete a research project in the automatic synthesis of digital designs. *Prerequisite: C programming language, undergraduate level digital design and VLSI design.*

ECE 3497 Statistical Signal Processing (4QH)
Fall Quarter

Introduction to Statistical Signal Processing; optimum filtering: principle of orthogonality, spectral factorization and the innovations process, Weiner and Kalman filters: Linear Prediction and Autoregressive Models: Gram-Schmidt orthogonalization and triangular matrix factorization, autoregressive model matching and the Yule-Walker equations, Order-Recursive Estimation: forward and backward prediction, lattice filter configuration, the Levinson and Schur algorithms, fast triangular factorization; Applications to adaptive arrays, echo cancellation, equalization, spectrum estimation, system identification, adaptive control, and speech analysis and synthesis: Estimation of Signal Statistics: autocorrelation estimates and their statistical properties, the deterministic least-squares approach, fundamentals of spectrum estimation, introduction to nonstationary spectrum analysis and estimation. *Prerequisites: ECE 3241 and ECE 3321.*

ECE 3500 Auditory Signal Processing (4QH)
As Announced

This course provides engineers interested in the processing and production of audio signals with knowledge of how sounds are processed and perceived in the auditory system by exploring physiological and psychological acoustics. Special emphasis is placed on mathematical models of the auditory system. Topics covered include: properties of acoustical stimuli; anatomy and physiology of the auditory system; electrical recordings from the auditory system; methods of psychophysical measurements; absolute thresholds; temporal integration; masking and auditory frequency analysis; signal detection theory and models of masking; frequency and intensity discrimination; experiments and models on temporal processing; loudness; Zwicker's loudness summation model; pitch perception; binaural hearing; other perceptual continua; timbre, roughness, noisiness, and annoyance. After completing the course, students will have a thorough understanding of the auditory processes that govern perception of sounds and are fundamental to our ability to understand speech. *Prerequisite: ECE 3241 or equivalent.*

ECE 3505 Digital Image Processing (4QH)
As Announced

Topics include: generation of digital image from the source, image digitizers and display devices, image transforms, enhancement techniques such as histogram, equalization, edge sharpening etc.; restoration by Wiener and Kalman filters, image coding using run length coding, DPCM, transform coding and feature analysis. *Prerequisite: ECE 3321.*

ECE 3508 Modern Spectral Analysis (4QH)
As Announced

This course starts with a description of the problem of estimating spectra from finite records of noisy data and a review of applications including biomedicine, geophysics, speech, non-destructive testing, sonar and radar, etc. It then explores many of the common power spectrum estimation algorithms, including both conventional and modern techniques. Emphasis is put on the advantages and limitations of conventional, Capon's, maximum entropy, parametric (AR, MA, and ARMA) and harmonic decomposition (Prony, Pisarenko, SVD) methods, in terms of accuracy (bias), reliability (variance) and other important criteria. Extensions to multi-channel and multi-dimensional data will be discussed, as well as a brief introduction to the array processing problem from a spectrum estimation perspective. The second half of the course will deal with higher order and non-stationary spectrum estimation, including both conventional and parametric higher order methods and sliding window (short-time Fourier transform and model-based), adaptive, time-frequency, and wavelet techniques for the non-stationary problem. *Prerequisites: ECE 3241 and ECE 3321. Recommend ECE 3497.*

ECE 3511 Network Communications and Performance Engineering (4QH)
(formerly Data Communications Networks)
Fall Quarter

Presents basic principles and topics of fundamental importance to the design and analysis of modern communications networks. Emphasis is placed on both theoretical and practical concepts. The objective is to provide students with the necessary analytical tools and intuition for advanced course work and research. The concept of a layered network architecture is used as a framework for understanding the principle functions and services required to achieve reliable end-to-end communications. Analysis of different switching and multiplexing techniques are presented within the context of network session requirements and, hence, network traffic characterization. Performance modeling is introduced with intermediate-level problems in queuing theory including MGI queues, simple queuing networks, the IPP and the MMPP. Point-to-point communications presents the backdrop for understanding the

complexities of networks. Models for transmission, encoding and fundamental limitations of physical channels are discussed as motivation for the development of data-link-layer services. Correctness and performance analysis are presented with respect to framing, error-detection and ARQ schemes. Local-Area-Networks (LANs) are discussed briefly as a special case of multiple access point-to-point communications. Host-to-host communications are presented as a problem of routing and addressing. Routing is discussed in detail, emphasizing correctness, stability and performance of fundamental algorithms. Students should gain insight into the problems of adapting traditional routing strategies to high-speed and wireless environments. Finally, flow and congestion control strategies are discussed and considered within the context of end-to-end session requirements and global network performance. *Prerequisites: ECE 3241 and C-Programming. Recommended: Statistics, discrete-event simulation and undergraduate networking course.*

ECE 3514 Error Correcting Codes (4QH)
As Announced

Error correcting codes and their decoding techniques which show promise for applications in digital communication, control and computer systems. Emphasis is placed on the linear block codes based on algebraic structures: cyclic codes for random error correction (B-C-H codes) and burst error correction. Convolutional codes and decoding including the Viterbi algorithm, arithmetic codes. Combination of codes. Coding for ranging and synchronization. *Prerequisite: ECE 3211.*

ECE 3526 Nonlinear Systems (4QH)
As Announced

Operators and functionals; The Volterra series representation of nonlinear systems; System Transforms; application of the Volterra theory to nonlinear system analysis: P-th order system inverses; the analysis of nonlinear feedback systems, circuits with nonlinear elements, and systems characterized by nonlinear differential equations. Introduction to orthogonal functionals. *Prerequisite: ECE 3108 or equivalent.*

ECE 3531 Adaptive Signal Processing (4QH)
Winter Quarter

Introduction to adaptive filtering: review of optimum filtering (Wiener-Kalman) and finite-order linear prediction; the stochastic gradient approach: Least-Mean-Squares (LMS) and normalized LMS adaptive FIR filters; Applications: equalization, noise cancellation, system identification, spectrum analysis, line enhancing, beamforming; the deterministic least-squares approach; Recursive Least Squares (RLS) adaptive filters: conventional RLS, QR-RLS; Comparative performance analysis of adaptive LMS and RLS filters: steady state error, tracking error, convergence rate and the role of orthogonalization, cost-performance trade-off; adaptive filter realizations that incorporate shift-invariance and orthogonalization: gradient and RLS lattice filters, RLS fast transversal filters (FTF); classification of adaptive (RLS)filters by: windowing-scheme, (prewindowed, sliding-window, unwindowed), architecture (triangular vs. linear, transversal vs. lattice), internal scaling (quotient, error-feedback, QR-based, etc.) and internal implementation; Multichannel adaptive filters; Finite precision effects in adaptive filters; introduction to adaptive IIR filters. *Prerequisite: ECE 3497.*

ECE 3534 Digital Processing of Speech Signals (4QH)
As Announced

Analysis and recognition of speech using computer techniques. Introduction to speech physiology, linguistics, phonetics, and acoustics. Models of speech production. Short-term processing of speech - temporal features, Fourier analysis, applications. Theory of linear predictive coding and applications. Homomorphic analysis of speech and applications. Speech and speaker recognition. *Prerequisite: ECE 3321.*

ECE 3537 Multi-User Communication Systems (4QH)
As Announced

Contention-free multiple-access techniques: frequency-division multiple-access (FDMA), time-division multiple-access (TDMA). Spread-spectrum multiple-access (SSMA) communications: Direct-sequence SSMA, frequency-hop SSMA, and hybrid SSMA systems. Communication networks: queuing theory, multiple-access with contention (ALOHA random-access and tree algorithms for random-access), network routing and flow control (quasi-static control versus dynamic control). An overview of the applications of multi-user communication systems: computer-communication networks, broadcast satellite systems, military communications, mobile radio communications, packet-radio communication networks, and fiber-optic local-area networks. *Prerequisite: ECE 3351.*

ECE 3540 Digital Control Systems (4QH)
As Announced

Analysis of linear discrete-time dynamic systems; discretization of continuous systems; sampling aliasing. Design of digital control systems using transform techniques by discrete equivalent and direct design methods; root locus, Bode and Nyquist diagrams and Nichols charts. Multivariant digital control using state-space methods; pole placement, observer, and regulator design. Controller implementation issues: digital filter realizations, nonlinear effects due to quantization, roundoff, deadband, limit cycles. Selection of the sampling rate. *Prerequisites: ECE 3221 and ECE 338l.*

ECE 3549 Multivariable Control Systems (4QH)
As Announced

Mathematical preliminaries, polynomial and polynomial matrices; representations of linear multivariable system; matrix fraction description (MFD) and polynomial matrix description (PMD); responses of linear multivariable systems; controllability, observability and canonical forms; poles and zeros of multivariable systems; stability; realization problem; interaction control; state feedback and observer design; compensator design, stability and robustness; noninteraction control; frequency domain design techniques. *Prerequisites: ECE 3221 and ECE 3381.*

ECE 3552 System Identification and Adaptive Control (4QH)
As Announced

Identification is the process of mathematically modeling a system based on measurement data that may be limited or uncertain. Adaptive control, then, is the means whereby a system that is poorly modeled is controlled adequately. The purpose of the system identification portion of the course is to enhance the underlying basic ideas, which are essential for

adaptive control. Particular emphasis is given to recursive approaches, such as recursive least square algorithm, where parameter estimates are updated in real-time. The adaptive control portion of the course covers simple adaptive systems, adaptive observers and adaptive control. Two major adaptive schemes, namely, Model Reference Adaptive Control (MRAC) and Self-Tuning Regulators (STR) are treated in detail. Fundamental issues such as stability of adaptive systems, convergence, persistent excitation, and robustness will be discussed. An important by-product of the course is that the students will identify several points of tangencies between two areas of control systems and signal processing. *Prerequisites: ECE 3221 and ECE 3321.*

ECE 3553 Spread Spectrum Communication Systems (4QH)
As Announced

This course introduces the fundamental concepts of spread spectrum communication systems. The basic theory of direct sequence (PN) and frequency hopping (FH) spread spectrum techniques will be studied in detail. Some important topics such as code generation and signal acquisition will also be covered. Some of the major characteristics of fading channels will be included as a complementary major subtopic. The performance of uncoded and coded spread spectrum communications in the presence of interference, jamming, and fading environments will be given considerable attention. The low probability of interception/detection (LPI/LPD) characteristics of spread spectrum techniques in multi-user communication systems will be included as a major topic. Various practical applications of spread spectrum will be presented, including some recent satellite mobile radio system designs. *Prerequisite: ECE 3351 or equivalent.*

ECE 3554 Advanced Topics in Communications (4QH)
As Announced

This course treats the design and performance analysis of modern digital communication techniques used in the realistic band-limited channels, including both the wired links, such as telephone and cable lines, and the wireless links, such as mobile radio channels. The following topics are treated in depth: 1) Signal design for band-limited channels according to Nyquist criteria, and optimum receiver design for intersymbol interference channels; 2) Equalization, including linear equalization, decision-feedback equalization, maximum-likelihood methods using the Viterbi algorithm, adaptive equalization and channel estimation, and blind equalization; 3) Multicarrier modulation methods or OFDM; 4) Spread-spectrum techniques, including direct-sequence and frequency-hopping for CDMA systems and for interference suppression; 5) Fading channel statistical characterization; and 6) Diversity techniques for fading channels, including spatial, frequency and time diversity, as well as multipath diversity through rake reception. The course is accompanied by a series of (Matlab) computer simulation exercises, which are used to substantiate the concepts studied in class, and are geared toward the development of each student's personalized communication system simulation toolbox. *Prerequisite: ECE 3351.*

ECE 3555 Statistical Pattern Recognition and Neural Networks (4QH)
As Announced

Pattern recognition problems arise in many areas of practical importance such as character recognition, computer vision, biomedical pattern classification and speech recognition. In this course pattern recognition problems are approached from a statistical point of view. Also neural networks as means of pattern recognition are studied. The subjects covered include: Bayes decision theory, discriminant functions, supervised and unsupervised learning, nearest neighbor classifiers, perception training algorithm, speech recognition, neural network fundamentals, feedforward neural networks and the back propagation algorithm, feedback neural networks, stable states, associative memory, capacity of neural networks. *Prerequisite: ECE 3241.*

ECE 3556 Special Topics in System Theory (4QH)
As Announced

Current aspects of system theory not covered in previous courses. Subject matter may change from year to year. *Prerequisites: ECE 3211 and ECE 3221.*

ECE 3557 Special Topics in Signal Processing (4QH)
As Announced

Aspects of signal processing not covered in other courses. Topics may vary from year to year. *Prerequisite: ECE 3321.*

ECE 3558 Digital Filter Banks and Wavelets (4QH)
As announced

This course develops the theory and applications of perfect reconstruction digital filter banks (PR filter banks) and continuous-time wavelet and wavepacket representations. The mathematical structure of the two disciplines are shown to be intimately related and the theory of both is developed both from a signal processing view point and an abstract mathematical view point. Applications that include signal processing and digital communications are examined in detail. Special emphasis is given to the multi-resolution analysis (MRA) of discrete and continuous-time signals and to applications that make use of this paradigm. *Prerequisite: ECE 3321.*

ECE 3559 Wireless Communications (4QH)
Spring Quarter

The course treats a diverse range of topics in wireless communications for applications such as cellular mobile radio, personal communication services (PCS) and wireless LANs (local area networks). Cellular system design, frequency reuse, channel assignment, handoff, power control, cell splitting, sectorization and system capacity. Radio propagation, path-loss models, log-normal shadowing, determination of coverage area, multipath and fading, statistical models for outdoor and indoor channels. Signal design principles: spectrum-efficient modulation methods (GMSK, $\pi/4$ QPSK), spread-spectrum modulation techniques (direct-sequence and frequency-hopping). Radio reception, receiver/transmitter architectures. Adaptive equalization (maximum-likelihood, linear and decision-feedback methods). Diversity techniques (selection, maximum ration combining, equal gain combining). Bit error rate and outage probability on fading channels. Multiple access for wireless systems: frequency, time, code and space division multiple

access (FDMA, TDMA, CDMA, SDMA). Wireless networking (packet-reservation multiple access, switching, mobility management for PCS). Standards for wireless systems: AMPS, IS-54, IS-95 (U.S. digital cellular based on CDMA), GSM (Global System Mobile) and the PCS standards. Future (third generation) systems and the International Mobile Telecommunications (IMT-2000). *Prerequisite: ECE 3351.*

ECE 3563 Radar Systems 1 (4QH)
As Announced

Emphasis on the systems aspects of radar engineering. Topics covered include basic theory of radar detection, measurement of range, angle, and Doppler shift; classes of radar systems; types of radar noise; components of a radar system; matched filters and correlation receivers as applied to radar systems; fundamental ideas of radar system analysis. In-depth study of search radar theory; maximum likelihood estimation approach to measurement of radar target parameters; resolution and ambiguity functions applied to radar; radar parameter uncertainty principles. *Prerequisite: ECE 3241.*

ECE 3566 Radar Systems 2 (2QH)
As Announced

Advanced topics in radar systems engineering. Topics to be covered include: design considerations for multistatic radar systems, synthetic aperture radars; tracking systems; radar waveform synthesis; multifunction array radar techniques and selected topics in radar sensing techniques and devices. *Prerequisite: ECE 3563.*

ECE 3567 Network Information Theory (4QH)
As Announced

This course deals with the fundamental limits on information compression and transmission in multi-user communication network from an information theoretic point of view. Topics covered in this course include: basics of point-to-point information theory, conditional AEP, capacity of channels with feedback, joint coding of correlated sources, source coding with side information, data compression with side information, multiple access channels, feedback in multiple access channels, broadcast channels and superposition coding, two-way channels, the wiretap channel. *Prerequisite: ECE 3241.*

ECE 3571 Fourier and Binary Optics (4QH)
As Announced

This course covers the fundamentals of Fourier and binary optics from a theoretical and a practical standpoint: radiation as a wave, polarization of radiation, reflection and refraction at surfaces, optical diffraction, scalar wave equation; Helmholtz and Kirchoff integral theorems, Fresnel and Fraunhoffer diffraction, Green's theorem, interferometry; division of amplitude, division of wavefront, diffraction gratings, multi-layer filters, interferometric instrumentation, holography. Imaging properties of lenses and optical systems, coherent and incoherent imaging, Modulation Transfer Function, spatial filtering, diffraction-limited optical systems, surface design of binary optical elements, miniature and micro-optics, fabrication of diffraction-limited optics, applications of diffraction-limited optics. *Prerequisite: ECE 3582.*

ECE 3574 Fourier Optics 2 (2QH)
As Announced

Covers current topics of interest in Fourier optics and optical instrumentation. Application of coherence phenomena to optical instrumentation such as microdensitometers, microscopes, viewers, cameras, spectraphotometric and interferometric instruments; applications of holography, optical data processing and computing, holographic memories, optical modulation, noise and its effects on data collection, synthetic aperture optics and medical application of laser optics. *Prerequisite: ECE 3571.*

ECE 3575 Lasers (4QH)
As Announced

Introduction to basic principles of lasers. Models for the interaction of electromagnetic radiation and matter. Laser threshold and rate equations. Resonator theory; transverse and longitudinal modes, and Rigrod analysis. Homogeneous and inhomogeneous broadening. Q switching, cavity dumping, and mode locking. Specific laser types including gas, liquid, and solid. Applications of lasers and laser systems. *Prerequisite: Admission to Graduate School.*

ECE 3579 Optoelectronics and Fiber Optics (2QH)
As Announced

This course covers the fundamentals of the optoelectronic elements that interconnect to create a fiber optic system for communication and sensing; structure of single and multi-mode fibers, step and graded index fibers, modal theory of fiber propagation, ray theory of multi-mode fibers, fiber parameters, numerical aperture, Etendue, modal cutoff; couple mode theory; semiconductor physics, diode lasers and LED sources; photovoltaic and photoconductive detectors; coupling sources and detectors to optical fibers; noise in fiber optic systems; active and passive components, modulators, couplers; fiber interferometry; applications in communication and sensing. *Prerequisite: ECE 3582.*

ECE 3582 Optics for Engineers (4QH)
As Announced

This course is an introductory graduate course in optics, presenting the engineering concepts necessary to understand and evaluate electro-optical systems. It begins with a brief but rigorous treatment of geometric optics, including matrix methods, aberrations, pupils and windows, with practical example of optical instruments and electro-optical systems. Other topics include polarization, interference, diffraction, and optical properties of crystals, thin-films, optical resonators, guided waves, modulators and detectors. The concepts are presented with examples from modern optical systems such as LIDAR, fiber-optical sensors, rangefinders, infrared systems, and optical communication systems. *Prerequisite: Bachelor of Science Degree in Engineering or Physics.*

ECE 3586 Optical Detection (4QH)
As Announced

The main emphasis of this course is on the detector as a critical component of an electro-optical system. Initial topics include descriptions of the different classes of detectors; imaging and non-imaging detectors, the scanning process, resolution and contrast, time and wavelength responses. These topics will be followed by a rigorous presentation of the mathematical basis of optical detection theory, including photon statistics, related noise issues (quantum noise,

background noise) and system limits (NEP, D*). Applications will be presented in the form of system studies, including LIDAR, optical communication, low-light level television, thermal imaging, sub-nanosecond and heterodyne detection. *Prerequisite: Bachelor of Science Degree in Engineering or Physics.*

ECE 3593 Plasma Engineering (4QH)
As Announced

Overview of the basic principles and applications of plasma and gaseous discharges. The topics include gas kinetics, interaction of electrons and ions with static and rf fields as well as wave propagation in plasmas. Applications in material processing, space exploration and microwave devices will also be discussed. *Prerequisite: ECE 3341.*

ECE 3594 Plasma Theory (4QH)
As Announced

Introduction to the basic theory of gaseous discharges. Fluid and kinetic description of collisionless and collisional plasmas with and without magnetic field effects. Emphasis will be placed on linear stability analysis, although nonlinear effects will also be discussed. *Prerequisite: ECE 3341.*

ECE 3597 Optical Properties of Matter (4QH)
As Announced

This course will present the formal mathematical treatment of classical crystal optics, including dispersion, polarization, birefringence, metal optics, and the optics of thin films. Special emphasis will be on the interaction of electromagnetic waves and the crystal lattice. Next, classical crystal optics will be extended to non-linear effects observed with very intense electric and magnetic fields. Applications of non-linear optics, such as second and third harmonic generation, optical mixing, optical parametric oscillation, multiple photon interaction, linear and non-linear scattering will be presented. Finally, various topics in linear and non-linear optics will be applied in areas such as birefringent filters, second-harmonic generators, optical parametric oscillators and acousto-optical beam deflectors. *Prerequisite: Bachelor of Science Degree in Engineering or Physics.*

ECE 3598 Remote Sensing (4QH)
As Announced

Introduction to the theory, instruments, and techniques for remote sensing of the earth. Topics include: fundamental properties of electromagnetic radiation; matter-energy interaction in the optical and microwave regions; optical imaging systems; synthetic aperture radar and side-looking airborne radar imaging systems; radar polarimetry; microwave scatterometry and radiometry; system considerations such as temporal and spatial resolution, operating frequency and bandwidth, calibration, measurement precision, and accuracy; data acquisition and storage; models and techniques for retrieving geophysical parameters from remotely sensed data; survey of current and planned airborne and spaceborne remote sensing systems and application of these sensors to measuring geophysical phenomena and monitoring global change. *Prerequisite: ECE 3341 and ECE 3241 or equivalent.*

ECE 3599 IR Imaging (2QH)
As Announced

This course covers the basic concepts necessary for understanding, designing, and evaluating electro-optical systems, including modern infra-red technology. Special emphasis will be given to considering the system as a whole, including radiation sources, the optical collection system, and the detection process. Performance characteristics and system limitations will be derived for a variety of imaging and non-imaging systems, as well as laser devices. Systems to be analyzed may include standard commercial television, night vision devices, laser rangers, thermal imagers, satellite imagers (LANDSAT, SPOT), optical communications and guidance systems. *Prerequisite: Admission to Graduate School.*

ECE 3600 Microwave Properties of Materials (4QH)
As Announced

General dielectric and magnetic properties of materials; tensor properties of dielectric and magnetic materials; special microwave properties of thin film materials; experimental techniques developed in the characterization of microwave materials. *Prerequisites: ECE 3102 and MIM 1245 or equivalent.*

ECE 3603 Propagation in Artificial Structures (4QH)
As Announced

Effective dielectric and permeability constants in composite materials at high frequencies; electromagnetic wave propagation in electrical and magnetic anisotropic media; magneto-static and magneto-elastic wave propagation in single layer; electromagnetic wave propagation in multi-layers. *Prerequisite: ECE 3102 or equivalent.*

ECE 3609 Special Topics in Electromagnetics (4QH)
As Announced

Inverse Scattering Theory and Applications. The course will concentrate on *inverse problems* associated with multidimensional wave equations such as the Schrodinger equation, Maxwell equations and the elastic wave equation. The theory will be developed using both the operator formalism employed in quantum scattering theory and the configuration space representations employed in electromagnetic and acoustic scattering theory. Specific topics covered in the course include the inverse Sturm Liouville problem, the deterministic and random inverse source problems, inverse diffraction, and the multidimensional inverse scattering problem. The theoretical development will be accompanied by a thorough review of current applications of inverse scattering theory which include structure determination using X-rays and electron probes, X-ray holography, geophysical prospecting and remote sensing, coherent radar imaging, and diffraction tomography. *Prerequisite: ECE 3231 or permission of instructor.*

ECE 3610 Electronics of Analog Signal Processing (4QH)
Winter Quarter

Circuit design of basic building blocks in analog signal processing and rf design are treated. Among the topics are operational amplifier architectures for low-voltage and high frequency applications, multipliers, oscillators, phase-locked loops, active filters and rf amplifiers. Designs are correlated with circuit simulations. *Prerequisites: ECE 3331.*

ECE 3613 Solid State Microwave Circuits (4QH)
As Announced

Design and analysis of solid state microwave circuits. Based on scattering parameters, design procedures for amplifiers are developed taking into consideration stability, power gain, noise, bandwidth and high power performance. Design of negative resistance oscillators based on small signal and large signal scattering parameters. The principles of design and operation of detectors and mixers using device non-linearity. Microwave control circuits including switches, phase shifters, limiters and attenuators. Circuits to produce frequency multiplication and division. Introduction to computer-aided design adoptimization using Touchstone and Libra software. *Prerequisite: ECE 3101 or equivalent.*

ECE 3626 Integrated Circuits Fabrication 1 (4QH)
As Announced

Overview of the basic techniques and processes employed in the fabrication of modern integrated circuits. Concentrates on the principles underlying the processes that are used to fabricate integrated circuits. Particular emphasis is placed on the processes that are most critical in the evolution of the technology; lithography and multilevel metallization. Discussions of yield and process integration for CMOS IC's and semiconductor memories conclude the course. *Prerequisite: ECE 3384 or equivalent.*

ECE 3629 Integrated Circuit Fabrication Processes: Plasma Processing (4QH)
Fall Quarter, Odd-numbered years

It is estimated that between 1/3 and 1/2 of the steps used to manufacture a modern integrated circuit involve gas plasmas. This course covers the fundamental behavior of low temperature plasmas used for integrated circuit fabrication. Plasma physics, plasma chemistry, and plasma reactor design will be discussed. These topics will be combined to develop a working knowledge of plasma etching, thin film deposition, and ion implantation. The course material will be covered at an introductory graduate level such that an undergraduate understanding of physics, chemistry, and electrical circuits serves as sufficient preparation. *Prerequisite: Admission to Graduate School.*

ECE 3632 Design and Analysis of Digital Integrated Circuits (4QH)
As Announced

The analysis and design of basic digital-integrated-circuit logic families are treated. Primary focus is on CMOS and BICMOS circuits; emitter-coupled logic (ECL) is also covered. Design considerations include propagation delay, switching speed, fan-out and the effect of parasitics. Noise, crosstalk and interconnect issues are discussed. Bistable circuits, clocks are treated. Design techniques are correlated with computer simulations. *Prerequisite: ECE 3101 or equivalent.*

ECE 3635 Antennas and Radiation (4QH)
As Announced

Presentation of the fundamental theory and properties of antennas: equivalence, reciprocity, uniqueness, Huygens principle, antenna impedance, diffraction; linear, loop, array, and aperture antennas, including horns, reflectors, lenses, and microstrip; transmitting and receiving antennas and transmission formulas, numerical antenna analysis methods. *Prerequisites: ECE 3341 and ECE 3344.*

ECE 3638 Microwave Electron Devices (4QH)
As Announced

The fundamental principles and operation of the principle types of conventional (linear-beam and crossed-field) and novel (maser effect) devices will be presented. Interactions of non-relativistic and relativistic electron beams with electromagnetic fields. Linear-beam tubes (klystron, traveling wave tube, backward-wave amplifier and oscillator etc.) crossed-field tubes (magnetron, forward and backward cross-field amplifier, high-gain CFA, etc.). Maser-effect devices (cyclotron maser, gyrotron). *Prerequisite: ECE 3341.*

ECE 3641 High Speed/High Frequency Solid State Devices (4QH)
As Announced

Schottky barrier diode, Gunn diode, p-i-n diode, IMPATT diode, MESFET, heterostructures; heterojunction bipolar transistor (HBT), high electron mobility transistor (HEMT), resonant tunnelling diode (RTD); photonic devices including light emitting diodes and lasers, noise properties. *Prerequisite: ECE 3384.*

ECE 3642 Microelectromechanical Systems (MEMS) (4QH)
As Announced

This course covers the Microelectromechanical Systems (MEMS) field at the graduate level. Tensor physics will be reviewed and used to describe physical properties of importance to sensors and actuators including; stress, strain, piezoresistivity, and elasticity. Students will examine methods which are used to predict the deflections of common mechanical structures used in MEMS. The course then covers both bulk and surface micromachining, including techniques for measuring properties of thin films including built-in strain, strain gradients and Young's modulus. The course concludes with a discussion of analysis and modeling of MEMS systems. Stability and noise will be covered. *Prerequisite: Admission to Graduate School.*

ECE 3644 Passive Microwave Circuits (4QH)
As Announced

The emphasis is on planar microwave circuits and applications in microwave integrated circuits. Review of the theory of scattering matrix and signal flow graphs. Characteristics of the stripline, microstrip, coplanar waveguide, slot line and fin line. Circuit discontinuities. Design of planar lumped elements: inductors, capacitors and resistors. Impedance matching and tuning including the operation of matching transformers. Microwave resonators including microstrip and dielectric resonators. Power dividers, directional couplers and hybrids. This will include the principle of operation of the Wilkinson power divider and the Lange coupler. Design of microwave filters using the image parameter method and insertion loss method. Filter transformations and implementation. Touchstone and Libra software is to be used in design problems. *Prerequisite: ECE 3101 or equivalent.*

ECE 3650 Local Area Networks and Inter-Networking (4QH)
As Announced

Presents fundamental principles and practical aspects concerned with the design and analysis of Local Area

Networks (LANs) and Internetworking strategies. Networks can be classified by numerous criteria. Properties including size, transmission speed, ownership and applications play an important role in understanding design an implementation decisions. The traditional definition of a LAN is that it provides relatively high-speed transmission within a limited geographic scope, and ownership is associated with the organization that uses and manages it. An alternative definition is that a LAN provides the physical and link-layer access point to an inter-network. LAN technology provides electrical, physical and signaling specifications, as well as the rules for transmission on various shared or dedicated media. Today LANs can operate at speeds in the Gigabits-per-second and may span great distances. Internetworking imposes a higher logical-layer abstraction that provides the protocols, algorithms and devices for interconnecting a mesh of heterogeneous LANs and intermediate networks into an internet. Thus, providing the means for a process running on a device connected to one LAN to communicate with a process on another device connected to a remote LAN. The objective of this course is to guide students through the evolution of LAN technology, from the challenges addressed by engineers designing first and second generation LANs, to present and future advances. The course emphasizes basic algorithms and protocols used for media access control and performance evaluation. Throughout the course internetworking concepts will be discussed and related to the protocols used in the present day Internet. *Prerequisite: ECE 3511 or equivalent. ECE 3351 Recommended.*

ECE 3652 Fundamentals of Computer Engineering (4 QH)
Fall Quarter

An introduction to fundamental techniques in computer engineering used throughout the graduate curriculum. Covers basic programming and analysis methods. Covers the formulation and solution of a wide range of computer engineering problems, with emphasis on applications from computer-aided-design, parallel computing, fault tolerant computing, computer networks, distributed processing, computer architecture, signal processing, robotics, fault-tolerant computing and coding. The applications of algorithm analysis and complexity theory to analyzing and solving problems will also be discussed. *Prerequisite: Admission to Graduate School.*

ECE 3653 Interconnection Networks for Multicomputers (4 QH)
As Announced

The topics to be covered in the course include: Static interconnection networks, topological properties of static interconnection networks, dynamic networks, routing in multicomputer networks, path setup, path selection (deterministic and adaptive), network flow control (store and forward, virtual-cut-through and wormhole) deadlocks in routine (virtual networks), multicasting and broadcasting in static networks (one-to-all broadcasting, all-to-all broadcasting, spanning graphs), fault tolerance and reliability of interconnection networks, performance metrics for different topologies (through-put, message latency, max delivery time, saturation point, hot spots, stable state, average link usage, dynamic hot spots identification). Modules for a realization of interconnection networks, Node's architecture and organization, based on 32 and 64 bits, CPU. Case studies. Router's architecture and organization. Case studies of different topologies and routine strategies. Fiber interconnect system (realization of point-to-point, arbitrary look, switching fabrics networks). *Prerequisite: ECE 3391.*

ECE 3654 Network Computing (4QH)
As Announced

The course will study in depth the theory and practice of analysis and design of network based computing systems. Network based computing appears to be the next high performance trend. The programs can be executed adaptively in a changeable computing environment, such as clusters of workstations or PC. The topics to be covered in the course include distributed shared memory. Cache coherence. Snooping. Locking. Atomic exchange. Deadlock. Message passing interface (MPI-1 and MPI-2). Point-to-point communication. Collective communications. Groups, contexts, and communicators. Process topologies (virtual topologies). Network of workstations (NOW). Protocols and programming. Scalable coherent interface (SCI) using point-to-point connection of distributed shared memory (DSM) machine. SCIs, Cache Coherence Protocol. Clusters of workstations based on SCI. Scalable networks for date processing-topologies, wormhole routing, deadlock avoidance, scalability, message format, fault tolerance, arbitration policies. Protocols and programming. Performance evaluation of network based computing systems. Case studies-ServerNet, myrinet, clusters of advanced workstations. *Prerequisite: ECE 3391 or ECE 3653.*

ECE 3655 Special Topics in Computer Networks (4QH)
Winter Quarter

Current aspects of computer communications networks not covered in previous courses. Subject matter may change from year to year. *Prerequisite: ECE 3511 or permission of instructor.*

ECE 3656 Mobile and Wireless Networking (4QH)
Winter Quarter

The purpose of this course is to introduce graduate students to the fundamental techniques and protocols in first and second generation, and emerging third generation wireless systems. This course examines how mobility affects networks, systems and applications. Mobility of devices and end-users has behavioral implications at all layers of the Internet protocol stack, from the MAC layer up through the application layer. Handling mobility efficiently requires more information sharing between network layers than is typically considered. Topics will include cellular system, medium-access-control protocols for wireless systems, mobility management and signaling within mobile networks, common air interfaces (AMPS, IS-136, IS-95, GSM), wireless data networking (CDPD) ad-hoc networks, Bluetooth, Mobile IP and PCS Systems. *Prerequisite: ECE 3511 or equivalent.*

ECE 3657 Broadband Communications Networks (4 QH)
As Announced

Broadband networks are designed to support a variety of services and applications. This course will cover the basic principles and fundamental design issues relevant to broadband communications networks and expose students to current research problems. The topics will range from SONET and ATM switching to high-speed network control. Specific topics that will be addressed include characterization

of network traffic and its implications on network design, traffic management, flow control and congestion control, including call admissions control, scheduling and policing, QoS-based routing and multicast routing. Networking technologies will reflect current research areas and implementations. The focus will be on high speed wide-area-networking (WAN) technologies such as Frame Relay (FR), Asynchronous Transfer Mode (ATM), and next generation Internet architectures. Methodology: Lecture, readings from relevant literature, student presentations. Prerequisite: ECE 3511 or equivalent.

ECE 3694 Special Topics (4QH)
Any Quarter

Topics of interest to the faculty member conducting this class are presented for advanced study. *Prerequisite: Consent of Department Chair.*

ECE 3797 Engineer Degree Thesis Continuation (0QH)

Candidates to register for thesis continuation if their thesis is not completed after they have registered for three consecutive quarters or ten quarter hours of EE degree thesis. Continuous registration is required until candidate graduates. **Please note that the Engineer Degree program has been terminated as of the 1998/99 academic year. The Engineer Degree Thesis and Engineer Degree Thesis Continuation courses apply to those students already in the Engineer Degree program.*

ECE 3798 Master's Continuation (0QH)
Any Quarter

ECE 3799 PhD Thesis Continuation (0QH)
Any Quarter

ECE 3860 Master's Thesis (8QH)
Any Quarter

Analytical and/or experimental work conducted under the auspices of the department. *Prerequisite: Bachelor of Science Degree in Engineering or Science.*

ECE 3861 Master's Thesis (4QH)
Any Quarter

ECE 3862 Master's Thesis (2QH)
Any Quarter

ECE 3863 Master of Science Project (4QH)
Any Quarter

Analytical and/or experimental work leading to a written report and a final exam consisting of a poster session together with a 5-minute presentation. The student is required to select an adviser, who will be responsible for the grade, and one other ECE faculty member. All MS Projects shall be presented at one poster session together with 5-minute presentations scheduled the Friday before final exam week. *Prerequisite: Permission of the Graduate Committee.*

ECE 3870 Engineer Degree Thesis (8QH)
Any Quarter

Analytical and/or experimental work conducted under the auspices of the department. Minimum of 4QH, maximum of 8QH allowed per quarter. *Prerequisite: Admission to Engineer Program. *Please note that the Engineer Degree program has been terminated as of the 1998 99 academic year. The Engineer Degree Thesis and Engineer Degree Thesis Continuation courses apply to those students already in the Engineer Degree program.*

ECE 3871 Engineer Degree Thesis (4QH)
Any Quarter

**Please note that the Engineer Degree program has been terminated as of the 1998/99 academic year. The Engineer Degree Thesis and Engineer Degree Thesis Continuation courses apply to those students already in the Engineer Degree program.*

ECE 3872 Engineer Degree Thesis (2QH)
Any Quarter

**Please note that the Engineer Degree program has been terminated as of the 1998/99 academic year. The Engineer Degree Thesis and Engineer Degree Thesis Continuation courses apply to those students already in the Engineer Degree program.*

ECE 3875 Master's Research (4QH)
Any Quarter

Investigation of Master's Research topic under supervision of individual faculty member.

ECE 3876 Master's Research (8QH)
Any Quarter

Investigation of Master's Research topic under supervision of individual faculty member.

ECE 3880 Doctoral Thesis (0QH)

Theoretical and/or experimental work conducted under the auspices of the department. *Prerequisite: Passing of PhD Qualifying Exam.*

ECE 3885 Doctoral Research (4QH)

Investigation of doctoral research topic under supervision of individual faculty member. *Prerequisite: Passing of PhD Qualifying Exam.*

ECE 3886 Doctoral Research (8QH)

Investigation of doctoral research topic under supervision of individual faculty member. *Prerequisite: Passing of PhD Qualifying Exam.*

ECE 3889 Doctoral Seminar (0QH)
Any Quarter

This requirement will be satisfied by the student presenting a seminar to the Electrical Engineering Department on a subject related to his/her PhD thesis. The thesis supervisor will coordinate the seminar. *Prerequisite: Passing of PhD Qualifying Exam.*

ECE 3890 Advanced Seminar (4QH)
Any Quarter

Treatment of advanced topics for research to include theoretical as well as experimental aspects. Reports and discussion of selected technical articles in professional journals and symposia.

ECE 3892 Doctoral Reading (0QH)
Any Quarter

Material approved by the candidate's adviser (only S or F Grades will be assigned for this course). *Prerequisite: Passing of PhD Qualifying Exam.*

ECE 3893 Special Problems in Electrical Engineering (2QH)
Any Quarter

Theoretical or experimental work under individual faculty supervision. *Prerequisite: Consent of Department Chairman.*

ECE 3896 Special Problems in Electrical Engineering (4QH)
Any Quarter

Theoretical or experimental work under individual faculty supervision.

Information Systems

The Graduate School of Engineering offers the degree of Master of Science in Information Systems. This program is designed for students and professionals who wish to make a career shift to the information systems field, or for professionals currently in the field who wish to enhance their skills and credentials. The many disciplines from which students switch include: liberal arts, life sciences, physical sciences, computer science, mathematics, business, and engineering. The successful applicant must demonstrate an inherent affinity for analytical thinking.

Applicants are required to submit GRE results, unless explicitly waived. Applicants who do not hold a degree from a U.S. university must submit TOEFL results as well. The program may be pursued on a full- or a part-time basis. Seminars are provided to introduce students to the information systems industry and to develop job-search skills.

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of forty-four quarter hours of credit and a minimum grade point average of 3.000 are required for the Information Systems degree. A maximum of twelve quarter hours of graduate credit from outside Northeastern University may be counted toward the degree. All transfer credits must be approved by petition before course enrollment.

It is expected that students beginning this program will have an adequate background in the following areas: C programming language, discrete structures, and probability and statistics. Deficiencies in this background may be remedied by taking the appropriate prerequisite courses listed below. All prerequisite courses must be taken unless waived by petition. A maximum of four quarter hours of graduate credit from the prerequisite courses may be applied to the degree as elective courses. Comparable courses may be substituted for prerequisite courses but only courses listed below may be applied toward the degree.

Courses from the College of Engineering not in the elective liston the following page, as well as courses from the College of Compute and Information Science and the College of Business Administration, may be considered for elective credit if a petition is filed.

Prerequisite Courses

		Credits
MTH 3212	Elements of Math for Information Systems 2 (Discrete Structures)	2
MTH 3214	Elements of Math for Information Systems 4 (Probability and Statistics)	2
MIM 3132	C/UNIX for Information Systems	4

Course Requirements

Core Courses	28 QH
Elective Courses	16 QH
Minimum Quarter Hours Required *	**44 QH**

* Includes a maximum of 4 QH of prerequisite courses.

Core Courses (28 QH)

			Credits
	MIM 3104	Data Structures	4
	MIM 3107	Operating Systems and Systems Software	4
	MIM 3110	Computer Architecture	4
	MIM 3115	Introduction to Software Engineering and Computer Technology	4
	MIM 3122	PC Architecture and Systems Programming	4
	MIM 3126	Networks and Telecommunications	4
	MIM 3128	Database Management Systems	4

Elective Courses (Select 16 QH*)

			Credits
	MIM 3102	Planning and Managing Information Systems Development	4
	MIM 3124	Software Engineering	4
Or	ECE 3311	Software Engineering	4
	MIM 3129	Expert Systems in Engineering	4
	MIM 3130	Machine Intelligence	4
	MIM 3131	Machine Learning	4
	MIM 3133	C++ Object-Oriented Design	4
	MIM 3137	Programming Languages for Software Engineering	4
	MIM 3140	Concepts of Object-Oriented Design	4
	MIM 3141	Component Software Development	4
	MIM 3142	Building Virtual Environments	4
	MIM 3143	Enterprise Software Development	4
	MIM 3217	Engineering Project Management	4
	ECE 3469	Fault-Tolerant Computers	4
	ECE 3480	Distributed Systems	4
	ECE 3483	Multiprocessor Architecture	4
	COM 3316	Transaction Processing Systems	4
	COM 3317	Data Modeling	4
	COM 3337	Distributed Operating Systems	4
	COM 3375	Human/Computer Interaction	4
	COM 3520	Cryptography and Computer Security	4
	COM 3560	Parallel and Distributed Database Systems	4
	MSC 3950	Fundamentals of Information Science **	3
	MSC 3952	Information Policy **	3

* Other courses may be used as electives with approval of the academic adviser.

** A maximum of one of these courses may be counted as an elective.

FACULTY

Dr. Ronald Perry, Program Director and Academic Adviser

Full-Time Faculty Associated with the Program

Electrical and Computer Engineering Department

Kaeli, David, Ph.D.
Kokar, Mieczyslaw, PhD

Mechanical, Industrial and Manufacturing Engineering Department

Cullinane, Thomas, PhD
Lee, Shiwoo, PhD
Mourant, Ronald, PhD
Zeid, Ibrahim, PhD

Part-Time Faculty Associated with the Program

Argo, Guy, PhD candidate, ITA Software
Bowes, Jr., John, MBA
Chikofsky, Elliot, MS, Engineering Management and Integration
Fisher, Edward, PhD
Gargeya, Radha, PhD, Axiowave Networks
Healey, Joseph, MS, Independent Consultant
Lupi, Robert, MA
MacIsaac, Don, MBA, Arbella Insurance
MacIsaac, Steve, MS, TSI Systems
Shridhar, Rajiv, MS, Northeastern University
Unver, Nilgun, PhD Candidate
Wilson, Charles, MS, MIT Lincoln Laboratory

Department of Mechanical, Industrial and Manufacturing Engineering

The Department of Mechanical, Industrial and Manufacturing Engineering offers the following graduate degree programs:

Master of Science in Mechanical Engineering
Master of Science in Industrial Engineering
Master of Science in Engineering Management
Master of Science in Operations Research
(In conjunction with the Mathematics Department)
Doctor of Philosophy in Mechanical Engineering
Doctor of Philosophy in Industrial Engineering

The department also hosts the following Graduate School of Engineering programs:

Master of Science in Computer Systems Engineering - CAD/CAM Option
Master of Science in Computer Systems Engineering - Engineering Software Design Option

Details for the Master of Science in Computer Systems Engineering degree can be found elsewhere in this catalog. Students accepted into the other Master's programs listed above must have a Bachelor of Science degree in engineering, science, mathematics, or equivalent. All programs may be taken either on a full- or part-time basis, but restrictions may apply.

A maximum of twelve quarter hours of graduate course work from outside the Department of Mechanical, Industrial and Manufacturing Engineering may be counted toward any master's degree in the department. These courses may be taken either within Northeastern University or from other institutions. All such transfer credit must be approved by petition.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING DEGREE REQUIREMENTS

A minimum of forty-four quarter hours of graduate study is required for this degree. Full-time students are required to complete a thesis for twelve quarter hours of credit. The thesis is not required of part-time students. All students must consult with their adviser or the Department's assigned Graduate Officer for course sequencing and the selection of elective courses in each area of

concentration. The curriculum offers areas of concentration in Mechanics and Design, Thermofluids Engineering, and Materials Science and Engineering.

Mechanics and Design

Course Requirements	Full-time Study	Part-time Study
Required Core Courses	16 QH	16 QH
Required Electives	12 QH	20 QH
Thesis	12 QH	0 QH
Other Courses	4 QH	8 QH
Minimum Quarter Hours Required *	**44 QH**	**44 QH**

* Exclusive of any preparatory courses.

Required Core Courses

			Credits
	MIM 3000	Mathematical Methods for Mechanical Engineers	4
	MIM 3600	Theory of Elasticity	4
	MIM 3630	Vibration Theory and Applications	4
	MIM xxxx	Required Core Course from Thermofluids Engineering	
Or		Materials Science and Engineering	4

Required Electives (12 or 20 QH from the following list)

		Credits
MIM 3615 - MIM 3695		
MIM 3005	Advanced Mathematical Methods for Mechanical Engineers	4
MIM 3010	Numerical Methods in Mechanical Engineering	4
MIM 3300	Manufacturing Design and Computers	4
MIM 3325	Robot Mechanics and Control	4
MIM 3350	Computer Aided Graphics and Design	4
	Advanced Electives in Mechanics or Design	

Thesis

		Credits
MIM 3925	Thesis (Master of Science Degree)	2
MIM 3930	Thesis (Master of Science Degree)	4
MIM 3935	Thesis (Master of Science Degree)	8

Other Courses (4 or 8 QH)

Advanced Courses in Engineering or Science with no more than six (6) quarter hours outside the major with the graduate adviser approval.

Thermofluids Engineering

Course Requirements	Full-time Study	Part-time Study
Required Core Courses	16 QH	16 QH
Required Electives	8 QH	8 QH
Thesis	12 QH	0 QH
Advanced MIM Electives	0 QH	12 QH
Other Courses	8 QH	8 QH
Minimum Quarter Hours Required *	**44 QH**	**44 QH**

* Exclusive of any preparatory courses.

Required Core Courses

			Credits
	MIM 3000	Mathematical Methods for Mechanical Engineers	4
	MIM 3700	General Thermodynamics	4
	MIM 3750	Essentials of Fluid Dynamics	4
	MIM xxxx	Required Core Course from Mechanics	
Or		Materials Science and Engineering	4

Required Electives Selection

		Credits
MIM 3710	Statistical Thermodynamics	4
MIM 3720	Heat Conduction and Thermal Radiation	4
MIM 3725	Convective Heat Transfer	4
MIM 3760	Viscous Flow	4
MIM 3765	Gas Dynamics	4
MIM 3792	Fundamentals of Combustion	4

Thesis

		Credits
MIM 3925	Thesis (Master of Science Degree)	2
MIM 3930	Thesis (Master of Science Degree)	4
MIM 3935	Thesis (Master of Science Degree)	8

Advanced MIM Electives (0 or 12 QH)

		Credits
MIM 3005	Advanced Mathematical Methods for Mechanical Engineers	4
MIM 3010	Numerical Methods in Mechanical Engineering	4
MIM 3300	Manufacturing Design and Computers	4
MIM 3325	Robot Mechanics and Control	4
MIM 3350	Computer Aided Graphics and Design	4

MIM 3710 - MIM 3795, excluding MIM 3750, and MIM 3800-3890

Other Courses (8 QH)

Advanced courses in engineering or science with no more than eight (8) quarter hours outside the major with the graduate adviser approval 8

Materials Science and Engineering

Course Requirements	Full-time Study	Part-time Study
Required Core Courses	20 QH	20 QH
Math Elective	4 QH	4 QH
Advanced Materials Electives	0 QH	12 QH
Advanced Courses in Engineering, Math, and Science	8 QH	8 QH
Thesis	12 QH	0 QH
Minimum Quarter Hours Required	**44 QH**	**44 QH**

Required Core Courses

		Credits
MIM 3800	Strengthening Mechanisms	4
MIM 3806	Phase Transformations	4
MIM 3820	Thermodynamics of Materials	4
MIM 3825	Electronic Behavior 1	4
MIM xxxx	Required Core Course from Mechanics or Thermofluids Engineering	4

* MIM 3000 and MIM 3700 are not eligible.

Math Electives

			Credits
	MIM 3000	Mathematical Methods for Mechanical Engineers	4
	MIM 3423	Applied Statistics	4
Or	MTH 3222	Applied Statistics	4
	MIM 3400	Basic Probability and Statistics	4

Thesis

		Credits
MIM 3925	Thesis (Master of Science Degree)	2
MIM 3930	Thesis (Master of Science Degree)	4
MIM 3935	Thesis (Master of Science Degree)	8

Advanced Materials Electives

		Credits
MIM 3665	Engineering Fracture Mechanics	4
MIM 3670	Advanced Engineering Fracture Mechanics	2
MIM 3800 - MIM 3890		26
CHE 3600	Polymer Science	4
ECE 3384	Solid State Devices 1	4
ECE 3388	Solid State Devices 2	4
ECE 3600	Microwave Properties of Materials	4
ECE 3626	Integrated Circuits Fabrication 1	4
ECE 3629	Integrated Circuit Fabrication Processes: Plasma Processing	4

Advanced Courses in Engineering, Mathematics and Science

These courses include those listed under Advanced Materials Electives as well as those in other departments in the University by the approval of the graduate adviser.

MASTER OF SCIENCE IN INDUSTRIAL ENGINEERING DEGREE REQUIREMENTS

This degree requires either an eight quarter hour thesis or a four quarter hour special project. Arrangements for and approval of the topic for the special project or thesis must be made with a member of the full-time faculty of the department. All MSIE students must take the core courses shown below. Equivalent substitutions must be approved by petition.

Course Requirements	With Thesis	With Project
Core Courses	24 QH	24 QH
Electives	8 QH	12 QH
Thesis or Project	8 QH	4 QH
Minimum Quarter Hours Required	**40 QH**	**40 QH**

Required Core Courses

		Credits
MIM 3215	Engineering Economy	4
MIM 3400	Basic Probability and Statistics	4
MIM 3423	Applied Statistics	4
MIM 3503	Simulation Methodology and Applications	4
MIM 3530	Operations Research 1	4
MIM 3320	Production Analysis	4

The remaining course work is satisfied by elective courses. A student may opt for a concentration in Computers and Information Systems, Manufacturing Systems, Operations Research, or Quality Control and Reliability Analysis by taking the required courses for the elective concentration listed below.

Courses for Elective Concentrations

Computers and Information Systems

		Credits
MIM 3104	Data Structures	4
MIM 3115	Introduction to Software Engineering and Computer Technology	4
MIM 3128	Database Management Systems	4

Manufacturing Systems (Any three of the following courses)

		Credits
MIM 3305	Manufacturing Methods and Processes	4
MIM 3310	Computer Methods in Manufacturing	4
MIM 3315	Neural Networks in Manufacturing	4
MIM 3375	Computer-Aided Manufacturing	4

Operations Research (Any three of the following courses)

		Credits
MIM 3503	Simulation Methodology and Applications	4
MIM 3524	Multi-Criteria Decision Making	4
MIM 3531	Operations Research 2	4
MIM 3532	Operations Research 3	4

Quality Control and Reliability Analysis

		Credits
MIM 3416	Statistical Quality Control	4
MIM 3425	Introduction to Reliability Analysis and Risk Assessment	4
MIM 3435	Reliability Engineering and Testing	4

MASTER OF SCIENCE IN ENGINEERING MANAGEMENT DEGREE REQUIREMENTS

The core course requirements for the Engineering Management program are listed below.

Course Requirements

Core Courses	24 QH
Electives	16 QH
Minimum Quarter Hours Required	**40 QH**

Required Core Courses

		Credits
MIM 3207	Financial Management for Engineers	4
MIM 3215	Engineering Economy	4
MIM 3217	Engineering Project Management	4
MIM 3400	Basic Probability and Statistics	4
MIM 3423	Applied Statistics	4
MIM 3530	Operations Research 1	4

The remaining course work is satisfied by elective courses. A student may select sixteen quarter hours of elective courses or opt for a concentration in Computers and Information Systems, Manufacturing Systems, Operations Research, or Quality Control and Reliability Analysis by taking the required courses for the elective concentration listed above.

MASTER OF SCIENCE IN OPERATIONS RESEARCH DEGREE REQUIREMENTS

The Master of Science in Operations Research (MSOR) degree is offered jointly by the Department of Mechanical, Industrial and Manufacturing Engineering, and the Mathematics Department. The program builds on the student's background in mathematics, science, or engineering to provide the skills needed to solve problems involving optimization, probability, and statistics. An applicant may apply for admission to the program through either the Department of Mechanical, Industrial and Manufacturing Engineering, or the Mathematics Department. Students will receive their degree from the college in which they are enrolled. The required and elective courses for the degree are specified below.

Course Requirements

Core Courses	24 QH
Electives *	16 QH
Minimum Quarter Hours Required	**40 QH**

* A thesis (8 QH) is optional in place of 8 QH of electives.

Required Core Courses

			Credits
	MIM 3400	Basic Probability and Statistics	4
Or	MTH 3431	Probability 1	4
	MIM 3423	Applied Statistics	4
Or	MTH 3441	Statistics 1	4
	MIM 3530	Operations Research 1	4
	MIM 3531	Operations Research 2	4
	MTH 3373	Optimization	4
	MTH 3432	Probability 2	4

The remaining course work is satisfied by sixteen quarter hours of elective courses. The following courses may be taken as electives:

MSOR Elective Courses*

		Credits
MIM 3104	Data Structures	4
MIM 3320	Advanced Production Analysis	4
MIM 3409	Design of Experiments	4
MIM 3425	Introduction to Reliability Analysis and Risk Assessment	4
MIM 3435	Reliability Engineering and Testing	4
MIM 3503	Simulation Methodology and Applications	4
MIM 3510	Forecasting	4
MIM 3512	Inventory Theory	4
MIM 3513	Network Analysis and Advanced Linear Programming	4
MIM 3515	Queuing Theory	4
MIM 3524	Multi-Criteria Decision Making	4
MIM 3532	Operations Research 3	4
MTH 3443	Statistical Decision Theory	4
MTH 3452	Time Series	4

			Credits
	MTH 3527	Enumeration	4
	MTH 3529	Graph Theory	4
	COM 3390	Analysis of Algorithms	4
	MTH 3535	Complexity Theory	4
Or	COM 3730	Complexity Theory	4

* Other courses may be selected with approval of an academic adviser.

THE DOCTOR OF PHILOSOPHY DEGREE

The degree of Doctor of Philosophy (PhD) is awarded to those candidates who demonstrate high attainment and research competence in the field of Mechanical Engineering or Industrial Engineering. Upon acceptance into the program, a student is designated a Doctoral *Student*. A doctoral student who has completed the equivalent of an MS program in Mechanical or Industrial Engineering or forty quarter hours of graduate work with satisfactory grades becomes a Doctoral *Candidate* upon successful completion of the Doctoral Qualifying Examination. After candidacy has been established, a candidate must complete a dissertation under the direction of a Dissertation Adviser and a program of course work. To receive the PhD degree a candidate must pass a Final Oral Examination.

Qualifying Examination

The Qualifying Examination is offered twice yearly, on the third Friday of November and May, and comprises both written and oral components. The objective of the written component is to test the student's knowledge and comprehension of the basic concepts and fundamentals in mechanical engineering and/or industrial and computer systems engineering. The oral component is administered to test general comprehension and capability for successful completion of the program. All Doctoral Students must take the qualifying examination within twelve months of acceptance into the program. Because degree candidacy must be established before the Graduate Committee will act to approve the course program and dissertation proposal, the qualifying examination should be taken at the earliest opportunity.

The written component is six hours in length and covers, with equal emphasis, four different areas from among the nine groups listed below. At least two of the four areas must be directly related to the student's research concentration. To provide breadth, at least one of the four areas must lie outside both the research concentration and Group A. The selection of all areas must be made in consultation with the Dissertation Adviser. All examinations shall be closed book and closed notes. Students may prepare and use a single double-sided 8½×11 sheet of reference materials for each examination. Students seeking guidance beyond that presented in *The Doctoral Qualifying Examination Handbook* as prepared and distributed by the Graduate Committee may speak with their advisers.

The oral component is conducted by a committee consisting of at least four members appointed by the Graduate Committee. A typical committee is composed of at least one member from each of the four specialty areas in which the student has chosen to be examined in the written component and includes the Dissertation Adviser.

Students will have a maximum of two attempts to achieve candidacy to the PhD program. Those not admitted to candidacy after the second attempt will no longer be eligible for candidacy in any of the department's PhD programs.

A student who is classified as interdisciplinary may request modifications in testing areas. The request must be approved by the Graduate Committee.

List of Groups and Areas:

A. Engineering Mathematics, Engineering Computation, Probability and Statistics
B. Thermodynamics, Fluid Mechanics, Heat Transfer
C. Dynamics and Vibrations, Mechanics of Deformable Bodies, Dynamic Systems and Control
D. Materials Science, Mechanical Behavior of Materials, Physical Metallurgy
E. Design and CAD/CAM
F. Human-Machine Systems
G. Manufacturing Systems, Production, and Logistics
H. Operations Research, Reliability and Quality Assurance, Simulation
I. Software Engineering, Programming Languages, Artificial Intelligence in Engineering

Dissertation and Course Requirements

Within two academic quarters after degree candidacy has been established, the doctoral candidate must petition the graduate committee to appoint a Dissertation Committee. The Dissertation Committee will be chaired by the student's dissertation adviser and must include at least two other members, with one member from outside the student's major area. The doctoral candidate will propose a Dissertation Topic and Program of Study to the Dissertation Committee for its approval within one year after degree candidacy has been established. A typical program includes at least thirty-six quarter hours of course work beyond the MS degree with a minor consisting of at least twelve quarter hours of the course work in a discipline other than that in which the candidate is concentrating (which may also be taken outside the department). Attainment of a minimum 3.000 grade point average for the courses in the minor portion of the program will signify satisfactory completion of that portion of the course work. Upon successful completion of the PhD qualifying examination and the majority of required course work, the student is required to register in three consecutive quarters for MIM 3985, Dissertation. Upon completion of this sequence, the student is required to register for MIM 3990, PhD Continuation, in every quarter until the dissertation has been completed. Students may not register for continuation until the three quarter thesis sequence has been fulfilled.

Final Oral Examination

A Final Oral Examination is scheduled after the Dissertation Committee agrees that the dissertation is in an appropriate form for formal presentation and after completion of all other requirements for the PhD degree. Upon successful completion of the examination, the doctoral candidate is recommended to receive the PhD degree.

Residence Requirement

The residence requirement is satisfied by one year of full-time graduate work or by two years of half-time graduate work beyond the Master of Science degree. However, a student should expect to spend at least three years, or the equivalent, in full-time graduate study beyond the requirements of the Master of Science degree.

FACULTY

John W. Cipolla, Jr., Chairman
Mohamad Metghalchi, Associate Chairman

Professors

Adams, George G., PhD, University of California at Berkeley; vibrations, elasticity, tribology, moving loads on structures, applications to information storage and processing systems

Busnaina, Ahmed A., PhD William Lincoln Smith Professor of Mechanical Engineering, Oklahoma State; Nano-scale particle adhesion and removal, contamination-free manufacturing in semiconductor processes, disk drive and image display microcontamination control, computational fluid dynamics, transport phenomena

Cipolla, Jr., John W., PhD, Donald W. Smith Professor of Mechanical Engineering, Brown University; laser-aerosol interactions including thermophoresis, heat and mass transfer, radiative transfer, kinetic theory

Cullinane, Thomas P., PhD, Virginia Polytechnic and State University; manufacturing systems, facilities planning, project management

Gorlov, Alexander M., PhD, *(Emeritus)*, Moscow Institute of Transport Engineers; mechanical design of complex systems, mechanical apparatus for harnessing tidal and low head hydro power, transporting of ships by land, general applied mechanics problems

Gupta, Surendra M., PhD, Purdue University; simulation, operations research, production systems, stochastic modeling, environmentally conscious manufacturing

Hashemi, Hamid N., PhD, Massachusetts Institute of Technology; materials, composite materials, nondestructive evaluation, mechanics, finite-elements, fatigue, wear, reliability-centered maintenance

Levendis, Yiannis A., PhD, California Institute of Technology; combustion, incineration, air pollution, chemical kinetics, aerosol physics, internal combustion engines

Metghalchi, Mohamad, Sc.D., Massachusetts Institute of Technology; laminar and turbulent flame propagation, stability in internal combustion engines, energy conversion, air pollution, chemical kinetics, advanced thermodynamics

Mourant, Ronald R., PhD, Ohio State University; human factors, software engineering, virtual environments and visualization, simulators for driving and manufacturing

Nowak, Welville B., PhD, Senior Research Scientist and Professor, *(Emeritus)*, Massachusetts Institute of Technology; materials science and engineering, thin films for resistance to corrosion, diffusion and wear, photovoltaic solar cells, electronic materials

Rossettos, John N., PhD, Harvard University; buckling and vibration of stiffened plates, mechanics of damage in composite materials, applied mechanics

Soyster, Allen L., PhD, Carnegie Mellon University; total quality management in acquisition process, applications of expert systems and artificial intelligence to building production scheduling systems, mathematical optimization of data analysis, modeling of energy distribution and transfer process

Taslim, Mohammad E., PhD, University of Arizona; computational and experimental fluid mechanics and heat transfer with applications in gas turbines, film cooling

Yener, Yaman, PhD, North Carolina State University; heat and mass transfer, radiative transfer, aerosolthermophoresis with radiation, thermal stability, spectral methods

Zeid, Ibrahim, PhD, University of Akron; CAD/CAM, design, manufacturing, case-based reasoning, Java and Web-based engineering applications

Associate Professors

Ando, Teiichi, Ph.D, Colorado School of Mines; physical metallurgy, rapid solidification, processing, powder metallurgy, spray forming, droplet-based materials processing and manufacturing, microstructural evolution in materials processing

Blucher, Joseph T., PhD, Massachusetts Institute of Technology; surface treating processes CVD, PVD, ion nitriding, laser processing, metal matrix composites, powder metallurgy, welding, cutting tools, manufacturing processes, failure analysis, fracture, fatigue, wear

Fard, Nasser, PhD, University of Arizona; reliability analysis, quality engineering, stochastic modeling

Isaacs, Jacqueline, PhD, Massachusetts Institute of Technology; processing and properties of metal matrix composites, environmental and life cycle issues in advanced and emerging technologies, manufacturing economics of materials processing in automotive industry

Kamarthi, Sagar, PhD, Pennsylvania State University; neural networks and knowledge-based systems in design and manufacturing, process monitoring and control, sensor integration, and product realization in mass customization

Kowalski, Gregory J., PhD, University of Wisconsin-Madison; combined modes of heat transfer in participating media, solar energy, thermal electronic packaging, combined heat and mass transfer

Melachrinoudis, Emanuel S., PhD, University of Massachusetts; operations research, stochastic modeling, facilities planning, manufacturing systems

Muftu, Sinan, PhD, University of Rochester; Fluid-structure interactions, flexible webs, gas lubrication, wave propagation in moving shells, contact wear and friction

Narusawa, Uichiro, PhD, University of Michigan; natural and double-diffusive convection in enclosures and saturated porous media, two-phase flows, thermocapillary flow

Perry, Ronald F., PhD, University of Michigan; simulation, management information systems

Assistant Professors

Benneyan, James C., Ph.D, University of Massachusetts; quality engineering, statistical quality control, inspection error models, computer simulation, industrial experiments, application in manufacturing and healthcare, including semiconductor fabrication and cancer screening

Lee, Shiwoo, PhD, Pennsylvania State University; information dissemination theory, information-driven manufacturing system design, visualization tool development

Program Advisers

Mechanical Engineering	
Mechanics and Design Concentration	Prof. H.N. Hashemi
Thermofluids Engineering Concentration	Prof. M. Taslim
Materials Science and Engineering Concentration	Prof. T. Ando
Industrial Engineering	Prof. S. Gupta
Engineering Management	Prof. T. Cullinane
Operations Research	Prof. E. Melachrinoudis
Computer Systems Engineering (CAD/CAM)	Prof. I. Zeid
Computer Systems Engineering (ESD)	Prof. R. Mourant

Each course description includes information on the expected quarter in which classes are usually offered. The quarters listed are presented here for planning purposes; however, the Graduate School of Engineering cannot guarantee that all courses will be offered. Students must refer to the Graduate School of Engineering Quarterly Course Offering booklets to determine what courses are actually offered in any given quarter. "Odd" and "Even" years refer to the fall quarter of the academic year, e.g., Spring 2003 which is in the 2002-2003 academic year, would be an "even" year.

MIM 3000 Mathematical Methods for Mechanical Engineers (4QH)
Fall Quarter

A comprehensive course designed to integrate undergraduate mathematics into a solid foundation of graduate mathematics. Topics will likely include infinite series, generalized functions and the Laplace transform, special functions, vector field theory, linear space theory, and eigenvalue and eigenfunction theory. These techniques and other methods will be used to solve both ordinary and partial differential equations. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3005 Advanced Mathematical Methods for Mechanical Engineers (4QH)
Fall Quarter, Odd Years

Variational calculus and applications. Complex variables. Approximate methods of engineering analysis. Integral transforms; asymptotic expansion; regular and singular perturbation methods. Examples drawn from solid mechanics, vibration, and fluid mechanics. *Prerequisite: MIM 3000.*

MIM 3010 Numerical Methods in Mechanical Engineering (4QH)
Winter Quarter

Numerical methods applied to problems in mechanical engineering. Solution of linear and non-linear systems of equations, interpolation and regression, numerical differentiation and integration, numerical solution of ordinary differential equations: explicit and implicit methods, multi-step methods, predictor-corrector methods. Numerical solution of partial differential equations with emphasis on parabolic and elliptic problems occurring in mechanical engineering. *Prerequisites: MIM 3000 and good knowledge of a programming language.*

MIM 3025 Human Factors Engineering (4QH)
Fall Quarter

Sensory motor and work environment considerations. Topics include the design of equipment and systems for human use with the application of engineering psychology; visual and auditory presentation of information; human information processing and skilled task performance. The human as a work-performing, heat generating physiological engine and the implied restrictions on the equipment and work place to provide occupational safety and effective man/machine performance. *Prerequisite: Admission to the Graduate School.*

MIM 3030 Human-Computer Interaction (4QH)
As Announced

This course considers the design of the computer-user interface. Emphasis is given to the needs and capabilities of the user, as well as to the computer- user interface designer's viewpoint. Ergonomic principles of design, particularly those pertaining to design of displays and controls, form a major component of the course. *Prerequisite: Admission to the Graduate Program.*

MIM 3102 Planning and Managing Information Systems Development (4QH)
Winter and Spring Quarter

Provides an overview of the most popular Information Systems (IS) needs assessment methodologies including Portfolio Analysis, Stage Assessment, Business Systems Planning and Alloway Survey Technique. Utilizes IS strategic plan components of business goal alignment, architecture planning, cost/benefit & risk analysis, and plan phasing techniques to demonstrate how businesses match needs to budgetary constraints. Options for the placement of the IS management function within the organization, methods to manage the function, and the use of business system planning tools to reengineer business processes are discussed and evaluated. Cases studies of actual business situations are utilized extensively. *Prerequisite: MIM 3115*

MIM 3103 Introduction to Formal Methods in Software Engineering (4QH)
As Announced

This course introduces mathematics and methods necessary for 1) formal specification of software requirements, 2) formal verification of software, 3) development of software through progressive refinement of specifications. Topics include propositional and predicate calculus, formal systems, theories of sets, relations, functions, sequences and algebras, model and theory based specification methods and examples, formal method tools, elements of theory of algorithm complexity. *Prerequisite: MIM 3124.*

MIM 3104 Data Structures (4QH)
Fall, Winter, and Spring Quarters

An introduction to basic concepts of data structures. Topics include arrays, stacks, lists, linked lists, queues, trees, graphs, symbol and hash tables, and files. An abstract data type for each data structure is presented and various implementations in a high level language are discussed. Algorithms for handling data are analyzed. Applications of particular structures are shown in order to emphasize abstraction in problem solving with computers. Searching and sorting techniques are also covered. *Prerequisite: MIM 3132 or equivalent, MTH 3212 or equivalent.*

MIM 3107 Operating Systems and Systems Software (4QH)

Fall, Winter, and Spring Quarters

An exploration of the underlying algorithms and policies which influence the development and execution of modern operating systems. Consideration will be given to operating systems facilities, which assist the design and implementation of application programs. The topics include process concurrency, synchronization, deadlock, multiprogramming, virtual memory, process scheduling, security, and protection. The UNIX operating system will be used as a model with several programming assignments using UNIX system calls. *Prerequisites: MIM 3104 and MIM 3110.*

MIM 3110 Computer Architecture (4QH)

Fall, Winter, and Spring Quarters

Fundamental concepts in computer architecture and organization are investigated. Topics include the history and evolution of computers; digital logic, gating, timing diagrams, and control signals; interconnection structures such as buses and data paths; data storage devices, interfaces, and organization; I/O devices and technology; interrupts and DMA; and cache and paging. An emphasis is placed upon CPU architecture, including binary arithmetic and organization of the ALU, instruction types, formats, addressing modes, and pipelining. Microprogramming of the CPU's control unit is considered in detail, and RISC architectures are surveyed. *Prerequisite: MIM 3122 or equivalent.*

MIM 3115 Introduction to Software Engineering and Computer Technology (4QH)

Fall and Winter Quarters

Introduction to software engineering analysis and design techniques and computer technology. Topics covered include: techniques for determining information requirements for MIS/DSSs; development of the functional systems design; and computer system design considerations such as the CPU, main memory, operating systems functions, computer languages, input devices, secondary memory, file organization, database management systems, data communications, data security, and output and display devices. The main objective of the course is to develop capability in the skeletal design of a computer system to support a given set of information requirements. *Prerequisite: Admission to Graduate Program.*

MIM 3122 PC Architecture and System Programming (4QH)

Winter and Spring Quarters

Presents fundamentals of the 80x86 family architecture and system programming. Topics covered include evolution of 80X86 architecture through the Pentium Pro, memory organization, assembly language coding, file handling, video display, keyboard operations, BIOS and DOS interrupts, and DOS/Windows command structure. The focus of the course is the popular interrupt-driven operating system DOS/Windows and its underlying system programming concepts. Concrete understanding of concepts are enhanced through laboratory exercises. *Prerequisite: MIM 3132.*

MIM 3124 Software Engineering (4QH)

Spring and Summer Quarters

A study of the software life cycle (requirements analysis and specification, software design, coding, testing, and maintenance). Verification, validation and documentation at various stages of the life cycle. Coverage of the Unified Modeling Language as applied to the software life cycle. Applications of design patterns. Overviews of user interface design, software metrics, and software development environments. Emphasis on modular software construction and development of modular libraries. Course requirements include a small software development project. *Prerequisite: MIM 3133, MIM 3140 or permission of Instructor.*

MIM 3125 Software Development and Evolution (4QH)

As Announced

The goal of this course is to introduce the students to the computer-aided software engineering (CASE) tools that aid in all the stages of software development. Topics include tools for documenting, requirements analysis and specification, validation and verification, software design and development, software generation, testing, and maintenance. *Prerequisite: MIM 3124.*

MIM 3126 Networks and Telecommunications (4QH)

Winter Quarter

Network goals and applications; architecture, topologies, and protocols; layered communications protocol design; layer functions, interlayer interfaces, and peer processes; performance measures; data communication techniques; wide area and local networks; channel interfaces and access schemes; workstations and server nodes; distributed systems; internetworking. *Prerequisite: MIM 3104.*

MIM 3128 Database Management Systems (4QH)

Fall, Winter, and Spring Quarters

Fundamental concepts and design of database management systems (DBMS). Topics include the role of DBMS in organizations; alternative database models - hierarchical, network and relational; underlying data structures for each database model; example DBMS for each model type; design of an information system using a DBMS approach; practical experience with at least one DBMS on a microcomputer or minicomputer, such as RBase 5000 or Data-Trieve. *Prerequisite: MIM 3104.*

MIM 3129 Expert Systems in Engineering (4QH)

Spring Quarter

An introduction to the theory, topics and applications of expert systems in engineering. Topics include knowledge representation (semantic networks, frames, production rules, logic systems), problem solving methods (heuristic search algorithms, forward and backward chaining, constraint handling, truth maintenance), approximate reasoning methods (Bayesian, Dempster-Shafer, fuzzy logic, certainty factors), expert system project management and knowledge engineering, expert system shells. Development of an expert system for engineering using an expert system shell is part of the course requirements. *Prerequisite: Admission to Graduate Program.*

MIM 3130 Machine Intelligence (4QH)

Fall Quarter

This course deals with the area of intelligent computer systems, i.e., such that exhibit some behavior normally attributed to humans - solving problems, reasoning, learning, handling collections of expert knowledge. This course focuses on

methods, techniques and implementations of computer systems for problem solving in the area of engineering. Topics include an overview of the field of artificial intelligence (AI), one of the AI programming languages (LISP or Prolog), knowledge representation formalisms and their implementations, search strategies and algorithms, planning, logic and theorem proving, constraint handling and truth maintenance systems, reasoning with uncertainty and heuristics, qualitative reasoning, and applications of artificial intelligence in engineering. *Prerequisite: MIM 3104.*

MIM 3131 Machine Learning (4QH)
Winter Quarter

This course introduces the students to the problem of developing programs that can learn (i.e., increment their knowledge in the process of execution). It covers some basic principles, techniques, tools and algorithms for building learning systems. The course concentrates on the methods of implementation of the learning algorithms in software rather than on the human learning mechanisms. Classification of machine learning methodology, algorithms, and programs is discussed. Current research being conducted in the field of machine learning at various institutions throughout the world is presented. *Prerequisite: MIM 3130.*

MIM 3132 C/UNIX for Information Systems (4QH)
Fall, Winter, and Spring Quarters

An introductory programming course using the C programming language and the UNIX operating system. Emphasis on structured programming techniques. Topics covered include algorithms and modular design of code; data types, control structures, submodules, structures and arrays, recursion, input/output processing, pointers, abstract data types, UNIX system interface and shell programming. Note: This course is designed for students with no programming language experience. *Prerequisite: Admission to Graduate Program.*

MIM 3133 C++ Object Oriented Design (4QH)
Fall, Winter, and Spring Quarters

An introduction to the basic concepts of C++ and object-oriented design for engineering software design and information systems. Topics include data abstraction, constructors and destructors, inheritance, the C++ I/O library, overloaded operators, virtual functions and polymorphism, and the reference data type. Applications of C++ programming are shown in order to emphasize the use of classes in problem solving with computers. *Prerequisite: MIM 3104.*

MIM 3137 Programming Languages for Software Engineering (4QH)
Spring Quarter

An introduction to programming languages is presented through a consideration of available procedural languages and of the principles of their design and implementation. Languages are surveyed historically, and insight is provided into aspects of programming languages such as control structures, parameter passing conventions, run-time structures, and binding time. Exposure to modern representative languages is given, including limited hands-on experience with block-structure languages, object-oriented languages, and languages for list processing and logic programming. *Prerequisite: MIM 3104.*

MIM 3140 Concepts of Object-Oriented Design (4QH) (Formerly Java with Engineering Applications)
All Quarters

Introduction to object-oriented design and programming via the Java programming language; the use of inheritance and composition in software design; development of Java applets and applications; study of the Java class libraries including the swing toolkit for building human computer interfaces, the network package for development of client-server systems. A course project is required. *Prerequisite: Knowledge of C programming.*

MIM 3141 Component Software Development (4QH) (Formerly Advanced Java Development)
Winter Quarter

Coverage of advanced topics in Java such as accessing databases with Java Database Connectivity (JDBC), the JDBC security model, the Remote Method Invocation (RPI) package, use of the Common Object Request Broker Architecture (CORBRA) with Java, the Java Native Methods Interface (JNI) and Java's Component Technology: Java Beans. *Prerequisite: MIM 3140.*

MIM 3142 Building Virtual Environments (4QH)
Spring Quarter

An object-oriented approach to building three-dimensional virtual worlds. The Java 3D API will be used to construct a scene graph and to control viewing and rendering. The scene graph, a treelike structure which includes geometric data, attribute information, and the information needed to render the scene from a particular point of view will be studied. A student project to program behaviors in a virtual environment will be required. *Prerequisite: MIM 3140.*

MIM 3143 Enterprise Software Development (4QH)
Fall Quarter

An object-oriented approach to the study and creation of server-side applications using Java servlets. Examination of distributed computing protocols including HTTP, RMI, and CORBA. Coverage of database connectivity with JDBC, applet-servlet communication, interservlet communication, and electronic commerce. Programming examples using the JavaBeans enterprise framework. A student project to develop and enterprise application will be required. *Prerequisite: MIM 3140.*

MIM 3152 Software Engineering Project 1 (4QH)
Winter Quarter

Team work under faculty supervision on a large software project. The projects are drawn from an engineering field, design, systems engineering, manufacturing, planning maintenance, reliability, quality control, risk assessment, project control, evaluation of alternatives, etc. The project may cover either the whole software development life cycle or a significant part of it. *Prerequisite: MIM 3124.*

MIM 3153 Software Engineering Project 2 (4QH)
Spring Quarter

Continuation of MIM 3152. *Prerequisite: MIM 3152.*

MIM 3204 Engineering/Organizational Psychology (4QH)
Fall and Spring Quarters
An analysis of the purpose and functioning of organizations as the basic networks for achieving goals through coordination of effort, communication, and responsibility. The role and function of engineering organizations based on modern behavioral science concepts. The application of psychology to industry relative to human relations, group dynamics, tests and measurements, personnel practices, training, and motivation. *Prerequisite: Admission to Graduate Program.*

MIM 3207 Financial Management for Engineers (4QH)
Winter and Spring Quarters
Study of the issues and processes of short-term financing on industrial firms; financial analysis of cases supplemented by readings to develop familiarity with sources and uses of working capital as well as the goals and problems involved in its management. Also covered is the analysis necessary for such long-term financial decisions as issuance of stock or bonds; contracting of leases or loans, and financing of a new enterprise; mergers, capital budgeting, the cost of capital, and the valuation of a business. *Prerequisite: Admission to Graduate Program.*

MIM 3215 Engineering Economy (4QH)
Winter Quarter
Economic modeling and analysis techniques for selecting alternatives from potential solution to an engineering problem are explored. Measures of merit such as present worth, annual worth, rate of return, and benefit cost techniques are considered. Recent techniques of economic analysis, especially the tools of decision making will be examined. Decisions under uncertainty are explored. *Prerequisite: MIM 3400.*

MIM 3217 Engineering Project Management (4QH)
Fall and Spring Quarters
The optimization of schedules utilizing pertinent software tools such as the linear programming and project management packages will be undertaken. Other graphics software used to draw project diagrams such as Gantt charts, PERT diagrams, manpower loading charts, and funding charts will be included. Determination of the critical path and comparison of actual performance with the planned schedule will be covered. The systems life cycle will be considered. Needs analysis, requirements definition, preliminary design, detailed design and implementation will be addressed in the context of project management. *Prerequisite: Admission to Graduate Program.*

MIM 3300 Manufacturing, Design and Computers (4QH)
Spring Quarter
Focuses on manufacturing and its relationship to design and computers. Covers fundamentals of manufacturing methods and systems. Examines relationship between design and various aspects of manufacturing. Computer modeling and related aids of various manufacturing activities are discussed. Topics include manufacturing systems, manufacturing processes, mechanical tolerancing, manufacturing features, process planning, principles of part programming (NC, CNC, DNC), and integration between CAD and CAM databases. Includes discussions of CAM packages. Students may gain hands-on experience by using in-house CAD and CAM facilities. *Prerequisite: Admission to Graduate Program.*

MIM 3305 Manufacturing Methods and Processes (4QH)
Fall Quarter
The structures of polymers (thermoplastic, thermosetting and glasses). Manufacturing processes for polymers, including thermoforming are included. Structure of metals and the manufacturing processes for metal forming are presented. Alloys, welding, and brazing are also included. *Prerequisite: Bachelor of Science Degree in Engineering or Science.*

MIM 3310 Computer Methods in Manufacturing (4QH)
Spring Quarter
In-depth coverage of the use of computers in the system design and implementation of Computer Integrated Manufacturing (CIM) is presented. Possible topic areas are the ICAM definition language for modeling process, MRP, project management, manufacturing simulation and facility layout, CAD/CAM, database interface, and other important application of computers to manufacturing systems. *Prerequisites: MIM 3375, MIM 3503, or permission of instructor.*

MIM 3315 Neural Networks in Manufacturing (4QH)
Winter Quarter
This course covers applications of neural networks to problems in manufacturing. The course will review background material on important neural network architectures, such as feedforward neural networks, Kohonen's feature maps, radial basis function networks, and adaptive resonance theory networks. The major emphasis of the course will be neural network applications in several areas such as group technology part family formation, conceptual design, manufacturing systems design, process optimization, process and machine tool monitoring and diagnosis, system identification and control, and product inspection. *Prerequisite: Admission to Graduate School.*

MIM 3320 Advanced Production Analysis (4QH)
Spring Quarter
Modern quantitative techniques of production planning and control considering deterministic and probabilistic models are presented. Topics include project planning, forecasting, aggregate planning and master scheduling, inventory analysis and control, materials requirement planning, job shop scheduling, and dispatching problems. *Prerequisites: MIM 3400 and MIM 3530.*

MIM 3325 Robot Mechanics and Control (4QH)
Fall Quarter
Kinematics and dynamics of robot manipulators are the focus of the first part of the course. Kinematics cover the development of kinematic equations of manipulators, the inverse kinematic problems, and motion trajectories. Dynamics of manipulators for the purpose of control are covered employing Lagrangian mechanics. The second part of the course focuses on the control and programming of robot manipulators. Steady state errors and calculations of servo parameters are covered. High level programming languages are discussed. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3350 Computer-Aided Graphics and Design (4QH)
Winter Quarter

Basic aspects of interactive computer graphics are covered. Topics include hardware and software concepts, design principles for the user-computer interface, geometrical transformation, display architecture, and data structures. Algorithms for removing hidden edges and surfaces, shading models, and intensity and colors are also covered. The second part of the course deals with the concepts of computational and numerical geometry and design of curves and surfaces. Solid modeling techniques are presented. Discussions of in-house computer-aided graphics and design packages are included. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3375 Computer-Aided Manufacturing (4QH)
Winter Quarter

A first course (overview) of computer-aided manufacturing. Covers the areas that encompass the term CAM, i.e., group technology, material requirements planning, part coding and classification, numerical control, part programming, and management systems. Broad coverage of each of the areas is given to allow the student to gain an appreciation of the coming review of the automated factory. *Prerequisite: Higher level language.*

MIM 3400 Basic Probability and Statistics (4QH)
Fall and Winter Quarters

Fundamental concepts of probability. Events, sample space, discrete and continuous random variables. Density functions, mass functions, cumulative probability distributions, and moment generating functions. Expectation of random variables. Common discrete and continuous probability distributions, including binomial, Poisson, geometric, uniform, exponential, and normal. Multivariate probability distributions, covariance and independence of random variables. Sampling and descriptive statistics. Parameter estimation, confidence intervals, and hypothesis testing. *Prerequisite: Admission to Graduate Program.*

MIM 3409 Design of Experiments (4QH)
Spring Quarter

Theory and application of experimental design techniques such as modeling and statistics which can optimize resources and improve decision making risks. This course will cover experiments with single and multiple factors of interest and consider experiments with high order experimental restrictions. Some additional analysis techniques will also be covered. *Prerequisite: MIM 3423.*

MIM 3416 Statistical Quality Control (4QH)
Spring Quarter

This course is designed to study the fundamental concepts of quality planning and improvements. Analysis and application of modern statistical process control methods, inspection error, and design of sampling plans will be given. Topics also include software quality assurance and study of the concepts of Deming, Ishikawa, Feigenbum, and Taguchi's approach in quality planning, organization, and improvement. *Prerequisite: MIM 3400.*

MIM 3423 Applied Statistics (4QH)
Fall and Winter Quarters

This course develops statistical models for analysis and prediction of random phenomena. Topics include review of descriptive statistics and hypothesis testing; linear models, both regression and ANOVA; chi-squared and non-parametric tests; and introduction to design of experiments. Emphasis will be placed on applying linear models in real life situations. *Prerequisite: MIM 3400.*

MIM 3425 Introduction to Reliability Analysis and Risk Assessment (4QH)
Fall Quarter

Introduction to probability theory, classical and Bayesian statistics useful for reliability analysis of large, complex systems. Bayesian probability encoding of experience data; principles of the methods of risk assessment and reliability analysis including fault trees, decision trees, and reliability block diagrams. Practical applications to industrial operations, e.g., nuclear and chemical plants, military systems, and large processing plants, are treated. *Prerequisite: MIM 3400 or permission of instructor.*

MIM 3435 Reliability Engineering and Testing (4QH)
Spring Quarter

This course is intended to acquaint the students with the evolving methodology of reliability as a design parameter. The problems of quantifying, assessing and verifying reliability are studied. Various factors that determine the stress and strength of components and their impact on system reliability are presented. Practical applications, examples, and problems cover a broad range of engineering fields, such as mechanical, electrical, industrial, computer, structures and automatic control systems. *Prerequisite: MIM 3400.*

MIM 3440 Total Quality Control for Engineering (4QH)
As Announced

Principles of Total Quality Control (TQC). Japanese management methods for technologies: manufacturing, electrical, steel, and automobile industries. Seven statistical methods of TQC: histograms, cause and effect diagrams, check sheets, Pareto diagrams, graphs, control charts, and scatter diagrams. Case studies of TQC implementation in technology management. Guest lectures by invited authorities. *Prerequisite: MIM 3400.*

MIM 3503 Simulation Methodology and Applications (4QH)
Fall and Spring Quarters

Covers when, where, and how to use discrete event simulation techniques. Topics include model design, development and validation; tactical and strategic planning considerations in the use of the model; input data reduction; alternative programming languages for implementing models; efficiency in running simulations, and statistical reliability in the design and analysis of simulation experiments. Several special purpose simulation languages are discussed, e.g. SIMSCRIPT, GPSS, and SIMAN. The opportunity to code models in one language is provided. *Prerequisite: MIM 3400.*

MIM 3505 Advanced Simulation Analysis (4QH)
Spring Quarter

The focus of this course is the statistically-based methodology of simulation analysis. Topics covered include selection of input probability distributions, random number and random variate generation, analysis of output streams, variance reduction techniques, and experimental design and optimization. We seek a thorough understanding of the theory underlying these issues and how they relate to the design and execution of statistically valid simulation studies. The level of discussion is state-of-the-art as defined by the latest published research results. In light of this background, an assessment of the effectiveness with which these issues are included in the major simulation languages (e.g., SIMAN, GPSS, SIMSCRIPT) is made. *Prerequisite: MIM 3503.*

MIM 3510 Forecasting (4QH)
Spring Quarter

Statistical forecasting procedures widely used in production planning and inventory control. Topics include introduction to regression analysis and statistical modeling for forecasting and control, moving averages and related methods, exponential smoothing methods, direct smoothing methods, seasonal smoothing models, autoregressive integrated moving average (ARIMA) models, interventional models, adaptive-control forecasting methods, and analysis of forecast errors. Forecasting experience using existing statistical computer programs is emphasized. *Prerequisite: MIM 3423.*

MIM 3512 Inventory Theory (4QH)
Fall Quarter

This course considers the nature and characteristics of inventory systems. It is concerned with techniques of constructing and analyzing mathematical models of inventory systems with a view towards determining operating policies for such systems. *Prerequisites: MIM 3400 and MIM 3530.*

MIM 3513 Network Analysis and Advanced Linear Programming (4QH)
Winter Quarter

Concepts of advanced linear programming and network algorithms are considered. Topics include: theory of the simplex method, the revised simplex algorithm, simplex for bounded variables, decomposition and column generation methods, complexity of the simplex algorithm and polynomial algorithms for linear programs, minimum cost network flows, network simplex, transportation, assignment and transshipment problems, and algorithms for solving maximal flow, minimum cut, and shortest path problems. *Prerequisite: MIM 3530.*

MIM 3514 Logistics, Warehousing, and Scheduling (4QH)
Winter Quarter

The determination of needs and requirements for logistics within large-scale systems and business environments are explored. Measures of logistics including reliability, maintainability, and supportability are examined. Systems maintenance concepts, logistics support analysis, and logistics in system design are covered. Warehousing and scheduling in the context of a business logistics system are introduced. Approaches to examining warehouses and the associated algorithms are considered. *Prerequisite: MIM 3400.*

MIM 3515 Queuing Theory (4QH)
Winter Quarter

Development of stochastic techniques used in queueing theory. Single and multiple server queues. Truncated queues. Complementarity and equivalence in queues. Queueing networks. Emphasis will be placed on theory as well as applications. *Prerequisite: MIM 3531.*

MIM 3524 Multi-Criteria Decision Making (4QH)
Winter Quarter

Theory, computation, and applications of multi-criteria decision making. Topics include techniques for generating noninferior solutions, techniques for finding the best-compromise solution, vector-maximum algorithms, filtering, multiattribute utility functions, analytic hierarchy process, goal programming and interactive methods. *Prerequisite: MIM 3530.*

MIM 3530 Operations Research 1 (4QH)
Fall and Summer Quarters

Introduction to the theory and use of deterministic models to represent industrial operations. It includes linear programming and networks. *Prerequisite: Course in linear algebra.*

MIM 3531 Operations Research 2 (4QH)
Fall and Winter Quarters

Introduction to theory and use of stochastic models to represent industrial operations. It includes dynamic programming, Markovian models, queueing, and inventory models. *Prerequisite: MIM 3400.*

MIM 3532 Operations Research 3 (4QH)
Spring Quarter

Important families of mathematical programming problems and optimization methods will be covered. The cutting plane and the branch and bound algorithm for binary and mixed integer programming problems. Introduction to nonlinear programming, including unconstrained optimization, the Kuhn-Tucker conditions, gradient methods, separable, quadratic, and geometric programming. *Prerequisite: MIM 3530.*

MIM 3600 Theory of Elasticity (4QH)
Winter Quarter

Analysis of Cartesian tensors using indicial notation. Stress and strain concepts, point stress and strain, relation to tensor concepts. Governing equations for the determination of stress and displacement distributions in a solid body. Exact solutions of the governing equations for elastic solids. Plane stress and strain problems in rectangular and polar coordinates, including thermal stress. Relation of elasticity theory to strength of materials. Torsion of prismatic and axially symmetric bars. Bending of thin flat rectangular and circular plates. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3615 Theory of Plates and Shells (4QH)
Spring Quarter, Odd Years

Theory of plates using classical theory (cylindrical bending, rectangular plates, circular plates). The combined effects of bending and in-plane forces. Buckling of plates. Effects of shear deformation and of large deflections. Membrane theory of shells. Analysis of cylindrical shells. General theory of thin elastic shells. Shells of revolution. *Prerequisite: MIM 3600.*

MIM 3620 Mechanics of Composite Materials (4QH)
Winter Quarter, Odd Years

Introduction to composite materials. Constitutive relations for anisotropic laminae and mechanical properties. Micromechanics models are used. Laminated composites and effects of stacking sequence. Selected topics include damage in fiber composite sheets. Application to structural response of beams and plates. *Prerequisite: MIM 3600.*

MIM 3625 Advanced Dynamics (4QH)
Fall Quarter, Odd Years

Kinematics of particles and rigid bodies, including moving reference frames. Modeling and application of fundamental laws of motion. Dynamic response of lumped parameter systems. Lagrange's equations. Applications in two and three dimensions. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3630 Vibration Theory and Applications (4QH)
Spring Quarter

Free and forced response to periodic and transient excitations. The vibration absorber. Free and forced response of multiple degree-of-freedom systems with and without damping. Method of modal analysis. Systems with distributed mass and stiffness. Extensional, torsional, and flexural vibrations of bars. Approximate methods of analysis. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3650 Automatic Control Engineering (4QH)
Fall Quarter, Even Years

Review of continuous-time system modeling and dynamic response, principles of feedback, classical control analysis and design techniques such as root-locus, and frequency-response. State-variable representation and optimal controller and estimator design introduced. Course project: modeling, analysis, and controller design of student-selected system. *Prerequisite: Undergraduate controls course or permission of instructor.*

MIM 3665 Engineering Fracture Mechanics (4QH)
Winter Quarter, Even Years

Fracture theory of brittle materials with crack-like defects. Energy release rate and stress intensity factor as fracture parameters. Linear elastic stress analysis of cracked structural components, with emphasis on how the stress intensity factor relates to geometric and loading parameters. Methodology for prediction of fatigue crack growth using fracture mechanics. Tests for measurement of fracture toughness and fatigue crack growth parameters. Optical fractography in failure analysis. Ductile fracture mechanisms and overview of nonlinear fracture mechanics. Probabilistic method for fracture prediction for ceramic materials with random populations of microscopic flaws. *Prerequisite: MIM 3600.*

MIM 3675 Advanced Mechanics of Materials (4QH)
Fall Quarter

Review of fundamental stress and deformation concepts; strain energy density; introduction to energy methods with application to beams, frames, and rings; Ritz method. Beams on elastic foundations. Concept of stability as applied to one and two degree-of-freedom systems. Buckling of bars, frames, and rings. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3680 Mechanics of Metal Forming for Manufacturing (4QH)
Winter Quarter, Even Years

This course will provide an introduction to the topic of the finite deformation of solids. The most common metal forming techniques will be presented. Experimental and theoretical constitutive descriptions of the large deformation of metals will be discussed, including von Mises yield surface, isotropic and kinematic hardening, Prandtl-Reuss constitutive laws, and viscoplasticity. They will then be applied to common metal forming operations, including rolling, forging, and sheet metal forming. Emphasis will be placed on the use of numerical techniques and especially finite elements to solve the complicated boundary value problems. Each student will use a commercial finite element package to solve and interpret a metal forming problem. *Prerequisite: MIM 3600.*

MIM 3690 The Finite Element Method (4QH)
Spring Quarter

Introduction to the finite element method. Variational formulations, simple interpolation functions, and element stiffness matrices. Triangular and rectangular elements. Assembly technique and constraining of resulting equations. Elementary applications. Isoparametic element formulation of higher order and three dimensional elements. Rayleigh-Ritz and Galerkin formulations. Applications of finite element theory to mechanical engineering problems in the areas of solid mechanics, heat transfer, and fluid mechanics. The use of a finite element general purpose commercial package is included. *Prerequisite: MIM 3000 or permission of instructor.*

MIM 3695 Experimental Techniques in Design (4QH)
Winter Quarter, Odd Years

In mechanical engineering, there is usually a need for verification of material properties, response simulation of the designed element, proof tests, and nondestructive testing of components. Design case histories will be utilized in defining appropriate experimentation needed for verification, simulation, proof tests, and inspection. These experiments may include, though they are limited to, tensile, fatigue, fracture toughness, vibration analysis, thermofluid analysis, and nondestructive testing. In this regard, the course will discuss the techniques associated with these experiments and methods of optimization of data and its acquisition. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3700 General Thermodynamics (4QH)
Winter Quarter

Fundamentals of equilibrium thermodynamics will be examined. Topics may include work, energy, heat, temperature, available energy, entropy, first and second law of thermodynamics, simple systems, closed and open systems, availability loss and irreversibility, heat engines, multicomponent systems, mixtures of gases, chemical reactions, and chemical equilibrium. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3710 Statistical Thermodynamics (4QH)
Spring Quarter, Even Years

An introductory course in statistical thermodynamics for Mechanical Engineers designed to provide insight into the laws of classical thermodynamics and the behavior of substances. Topics to be covered include: Introduction to probability; elementary kinetic theory of an ideal gas including the distribution of molecular velocities and the mean free path treatment of transport properties; classical statistics of independent particles, equipartition of energy, the partition function and laws of thermodynamics; some results from quantum mechanics, quantum statistics of independent particles; applications to gases; introduction to ensembles, and systems of interacting particles. *Prerequisite: MIM 3000 and MIM 3700 or equivalent.*

MIM 3720 Conductive Heat Transfer (4QH)
(Formerly Heat Conduction and Thermal Radiation)
Winter Quarter

Topics covered include formulation of steady and unsteady state one- and multi-dimensional heat conduction problems, solution techniques for linear problems, including the method of separation of variables, Laplace transforms and integral transforms, approximate analytical methods, phase change problems, and non-linear problems. *Prerequisite: MIM 3000 and undergraduate heat transfer.*

MIM 3725 Convective Heat Transfer (4QH)
Fall Quarter, Odd Years

Topics covered include fundamental equations of convective heat transfer, heat transfer in incompressible external laminar boundary layers, integral boundary layer equations, laminar forced convection in internal flows, turbulent forced convection in internal and external flows, analogies between heat and momentum transfer: the Reynolds, Taylor and Martinelli analogies; natural convection, heat transfer in high-speed flow, and transient forced convection. *Prerequisites: MIM 3750 and MIM 3720 or permission of instructor.*

MIM 3730 Radiative Heat Transfer (4QH)
(Formerly Radiative Transfer)
Fall Quarter, Even Years

Topics covered include electromagnetic background, nature of thermal radiation, radiation intensity, black body intensity, radiation through non-participating media. Fundamentals of radiation in absorbing, emitting and scattering media, equation of radiative transfer, methods of solution of the equation of radiative transfer, pure radiative transfer in participating media, and interaction of radiation with conduction and/or convection. *Prerequisite: MIM 3720.*

MIM 3735 Solar Thermal Engineering 1 (2QH)
As Announced

A model is developed for the hourly direct and diffuse radiation under a cover of scattered clouds and the transmission and absorption of this radiation by passive and active systems. The design of air heating systems and the storage of the collected energy by a pebble-bed are considered, as well as elements of heat exchanger design. A study of the economics of a domestic water and/or space heating system is made using f-chart analysis.

MIM 3740 Heat Transfer Processes in Microelectronic Devices (4QH)
Spring Quarter

Discussion and development of state-of-the-art methods used to predict the heat transfer rates from microelectronic devices and packages and to simulate transport phenomena in manufacturing processes associated with microelectronic devices. Topics will be selected from the current literature and may include use of latent heat reservoirs, boiling jet impingement cooling, control volume approaches to extended surfaces, calculation of thermal contact conductances and natural convection in enclosures. Simulation of laser assisted thermophoretic deposition and laser cladding processes will also be developed. *Prerequisite: MIM 3000 (or equivalent) and undergraduate heat transfer or permission of instructor.*

MIM 3750 Essentials of Fluid Dynamics (4QH)
Fall Quarter

A fundamental course in fluid dynamics designed to prepare the student for more advanced courses in the thermofluids curriculum while providing a strong background in fluid mechanics. Topics to be covered may include: Cartesian tensors; differential and integral formulation of the equations of conservation of mass, momentum and energy; molecular and continuum transport phenomena; the Navier-Stokes equations; vorticity; inviscid, incompressible flow, the velocity potential and Bernoulli's equation; viscous incompressible flow; the stream function; some exact solutions; energy equation including heat conduction and viscous dissipation. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3755 Two Phase Flow (4QH)
As Announced

The basic concepts of heat and mass transfer associated with phase change and multi-phase flows are covered. Some of the specific subjects to be discussed are boiling heat transfer (nucleate boiling, film boiling and bubble dynamics); evaporation and condensation; and liquid-gas two phase flow and gas-solid and liquid-solid two phase flows. *Prerequisite: MIM 3000 (or equivalent) and undergraduate heat transfer.*

MIM 3760 Viscous Flow (4QH)
Winter Quarter, Odd Years

Topics covered are: Review of conservation of mass, momentum, and energy for compressible viscous flow, discussion of the mathematical character of the basic equations and analysis of some exact solutions, investigation of low Reynolds number flow, exact and approximate approaches to laminar boundary layers in high Reynolds number flows, stability of laminar flows and the transition to turbulence, treatment of incompressible turbulent mean flow; internal and external flows, and extensions to compressible boundary layers. *Prerequisite: MIM 3000 and MIM 3750.*

MIM 3765 Gas Dynamics (4QH)
Spring Quarter, Odd Years

The consequences of fluid compressibility are studied. Shock waves and the theory of characteristics are discussed with specific consideration given to two-dimensional steady flows and one-dimensional unsteady flows. Additional topics may include axially symmetric steady flow, small perturbation theory, similarity rules, the hodograph method, or some aspects of physical acoustics. *Prerequisite: MIM 3750.*

MIM 3770 Computational Fluid Dynamics with Heat Transfer (4QH)
Spring Quarter

Topics covered include: Finite difference methods for solving partial differential equations with particular emphasis on the equations of fluid dynamics and convective heat transfer, integral methods for boundary layers and their coupling to potential flow solutions, use of coordinate transformations and body-oriented coordinate systems, and application of superposition techniques in convective heat transfer problems. *Prerequisites: MIM 3750 and MIM 3010.*

MIM 3775 Turbomachinery Design (4QH)
As Announced

Preliminary design methods and analytical tools applicable to turbomachinery are presented. Design criteria and performance characteristics at design and off-design operating conditions are discussed for several important types of turbomachinery. Axial flow compressors and turbines (gas and steam) are studied in some depth, including topics such as compressor surge, turbine blade cooling, and steam wetness effects. Centrifugal compressors, radial inflow turbine, pumps, fans, and water turbines are also studied. Turbomachinery mechanical design limitations are discussed. The use of empirical data on blade cascade performance in blade selection is examined. Numerical methods of analyzing two- and three-dimensional flows in turbomachinery (e.g., conformal transformation and streamline curvature) are presented. Two in-depth design projects are assigned. *Prerequisites: Admission to the Graduate School of Engineering, including undergraduate preparation in fluid mechanics and thermodynamics.*

MIM 3780 Aerosol Mechanics (4QH)
As Announced

This course studies the behavior of ultrafine particles from both microscopic and macroscopic viewpoints. First the microscopic origins of aerosol transport phenomena are discussed including Brownian diffusion, drag, thermophoresis, condensation, and evaporation. This is followed by a discussion of deposition processes for monodisperse aerosols, distribution functions for polydisperse aerosols, the general dynamic equation and methods of solution, homogeneous nucleation, and coagulation. Industrial applications will be introduced where appropriate. *Prerequisites: MIM 3000, MIM 3700, MIM 3750 or permission of instructor.*

MIM 3785 Turbulent Flow (4QH)
As Announced

Discussion of flow and transport with emphasis on engineering methods. Generation and dissipation of turbulence, fluctuations and time-averaging, Reynolds stresses and turbulent fluxes, closure models for free and bounded shear flows; models employed for practical flows, including k-E and algebraic-stress models; introduction to large eddy and direct simulation; and introduction to numerical modeling of turbulent flows. *Prerequisite: MIM 3750 or permission of instructor.*

MIM 3790 Macroscopic Transport in Materials Processing (4QH)
As Announced

Principles of mathematical and physical modeling of the processing of primary and electronic materials. Practical examples will include continuous casting, rheocasting, metal-matrix composites, thermal spraying, magnetohydrodynamics, microgravity processing, growth of semi-conductor crystals, and chemical vapor deposition. Transport equations will be discussed as tools of mathematical models and similarity criteria as tools of physical models. Topics will include Newtonian and non-Newtonian fluid mechanics, multi-phase flow, dimensionless numbers, conductive and convective heat transfer, thermal radiation, diffusion and mass transfer with chemical reaction, order-of-magnitude analysis, intelligent processing techniques. *Prerequisite: Undergraduate heat transfer or permission of instructor.*

MIM 3792 Fundamentals of Combustion (4QH)
Fall Quarter, Even Years

Comprehensive treatment of the problems involved in the combustion of liquid, gaseous, and solid fuels in both laminar and turbulent flow. The fundamentals of chemical kinetics will be discussed. The equations for the transport of mass, momentum, and energy with chemically reacting gases will be examined. Topics will include diffusion and premixed flames, combustion of droplets and sprays, and gasification and combustion of coal. *Prerequisite: MIM 3700.*

MIM 3795 Combustion and Air Pollution (4QH)
Fall Quarter, Odd Years

This course deals with the formation of pollutants during combustion processes and their subsequent transformations in the atmosphere. Emphasis will be placed on the effects of design and operating parameters of combustion devices on the nature and composition of exhaust gases, improvements, post-combustion treatment of effluent gases, atmospheric chemistry, and atmospheric transport of pollutants, smog formation, acid rain, ozone formation and destruction. *Prerequisite: Undergraduate course in thermodynamics, heat transfer, and fluid mechanics, or permission of instructor.*

MIM 3800 Strengthening Mechanisms (4QH)
As Announced

Dislocation theory including such topics as dislocation stress fields, self-energy, velocity, interactions mechanisms, image forces, and theories of yielding, mechanical behavior of metals. Application of dislocation theory to micro-plasticity, strain hardening, strengthening mechanisms, and creep. *Prerequisite: A recent introductory materials science course.*

MIM 3806 Phase Transformations (4QH)
Spring Quarter

Considers the different types of phase transformations that occur in metals and alloys in relation to theory and practice. The first part consists of a review of thermodynamics, with emphasis on the properties of solutions, their relation to phase diagrams, and the theory of diffusion. The student will then learn how to relate these fundamentals to the thermodynamics and kinetics of phase transformations and understand how phase transformations alter the microstructure of materials. Both diffusional and diffusionless phase transformations are covered. Examples of applications to materials processing and manufacturing are presented. *Prerequisite: MIM 3820.*

MIM 3815 Powder Metallurgy (2QH)
As Announced

Powder characteristics and methods of manufacture. Powder pressing: packing, interparticle bonding, effects of pressure; principles of sintering, characteristics and properties of products made from powdered materials. *Prerequisite: A recent introductory materials science course.*

MIM 3816 Powder Metallurgy (4QH)
As Announced

Methods for metal powder production, analysis, handling, compaction, and consolidation. Priciples of sintering in the absense and presence of liquid. Structure and properties of PM products. Advanced materials processing by powder metallurgy. *NOT open to those students who have taken MIM 3815. Prerequisite: Undergraduate materials science course.*

MIM 3820 Thermodynamics of Materials (4QH)
Fall Quarter

Basic materials thermodynamics encompassing first, second, and third laws, entropy, enthalpy, and free energy. Emphasis on solutions, activity, activity coefficients, the phase rule, and applications to some materials problems. *Prerequisite: Undergraduate Thermodynamics.*

MIM 3825 Electronic Behavior 1 (4QH)
Fall Quarter

Electronic principles underlying the structure and properties of solid materials, the relationships of these principles to the properties and to applications in structures and device, both macroscopic-phenomenological and electronic-molecular approaches will be used. Materials will include metals and alloys, semiconductors, and dielectrics. Typical subjects are electronic structures, band theory, thermal properties, and electrical conductivity. *Prerequisite: A recent introductory materials science course.*

MIM 3830 Electronic Behavior 2 (2QH)
Winter Quarter

Continuation of MIM 3825 into magnetic, dielectric, and optical properties. *Prerequisite: MIM 3825.*

MIM 3835 Corrosion 1 (2QH)
As Announced

The study of the thermodynamics of corrosion and corrosion reactions both in aqueous and non-aqueous environments. Topics will include thermodynamics, kinetics, and the effects of environment and physical metallurgy. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3839 Environmental Issues in Manufacturing and Product Use (4QH)
Spring Quarter

This course explores environmental and economic aspects of different materials used in a product throughout the life cycle. Concepts of industrial ecology, life cycle analysis, and technical cost modeling are introduced. Students work in teams to analyze case studies of specific products fabricated using metals, ceramics, polymers, and paper. These case studies compare cost, energy, resources used, and emissions generated through the mining, refining, manufacture, use and disposal stages of the product life cycle. Issues in legislation - manufacturer take-back, packaging, ecolabeling - and issues in disposal strategies - landfill, incineration, reuse and recycling - are debated. Difficulties associated with environmental impact assessments, and the development of decision analysis tools to weigh the tradeoffs in technical, economic, and environmental performance are discussed. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3840 Corrosion 2 (2QH)
As Announced

Continuation of MIM 3835. *Prerequisite: MIM 3835.*

MIM 3841 Corrosion of Materials (4QH)
As Announced

Embodies the material in MIM 3835 and MIM 3840. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3845 Electronic Materials (4QH)
As Announced

Generic techniques for fabrication and processing and the resulting structure-property relationships are presented for materials utilized in electronics. Typically included are bulk single crystals, thin films, metals, semi-conductors, and insulators. *Prerequisite: MIM 3825.*

MIM 3850 Diffraction Methods in Materials Science (4QH)
As Announced

Embodies the material in MIM 3855 and MIM 3859. *Prerequisite: A recent materials science course.*

MIM 3855 Introduction to Diffraction Methods in Material Science (2QH)
As Announced

General principles of the diffraction by materials of short wave length radiations (such as x-ray, electrons, and thermal neutrons) are studied with emphasis on the understanding of the similarities and differences of the different radiations when applied to the study of the structures of crystalline and non-crystalline materials. *Prerequisite: A recent introductory materials science course.*

MIM 3859 Diffraction Methods in Material Science (2QH)
As Announced

Continuation of MIM 3855 with emphasis on the experimental methods and applications. This includes choice of radiation, introduction to instrumentation, sample preparation, methods of detection and recording of the diffracted radiation, analysis, interpretation, and use of the results. *Prerequisite: MIM 3855.*

MIM 3860 Ceramics Processing 1 (2QH)
As Announced

Introduction to ceramic fabrication processes. Characteristics of vitreous and crystalline solids, structural imperfections, and atomic mobility. Phase equilibria, nucleation, crystal growth, solid-state reactions, non-equilibrium phases, and effects on the resulting micro-structure of ceramics. *Prerequisite: A recent introductory materials science course, physical chemistry, or solid state physics.*

MIM 3865 Ceramics Processing 2 (2QH)
As Announced

Discussion of effects of composition and microstructure on the thermal, mechanical, optical, electrical, and magnetic properties of ceramic materials. *Prerequisite: MIM 3860.*

MIM 3869 Ceramics Processing (4QH)
As Announced

Embodies the material in MIM 3860 and MIM 3865. *Prerequisite: A recent introductory materials science course, physical chemistry, or solid state physics.*

MIM 3870 The Structure and Properties of Polymeric Materials 1 (2QH)
As Announced
Introduction to the organic chemistry of polymers, effect of chemical composition on structure, melting point and glass transition temperature, polymer characterization and degradation, thermodynamics of polymers. *Prerequisite: Undergraduate materials science course.*

MIM 3875 The Structure and Properties of Polymeric Materials 2 (2QH)
As Announced
Rheology and mechanical behavior of polymers, analysis and testing, effects of processing on structure and physical properties, industrial polymers, resin base composites. *Prerequisite: MIM 3870.*

MIM 3880 The Structure and Properties of Polymeric Materials (4QH)
As Announced
Embodies the material in MIM 3870 and MIM 3875. *Prerequisite: Undergraduate materials science course.*

MIM 3900 Independent Study (2QH)
Any Quarter
Theoretical or experimental work under individual faculty supervision. *Prerequisite: Approval of Department faculty.*

MIM 3905 Independent Study (4QH)
Any Quarter

MIM 3910 Special Topics (2QH)
Any Quarter
Topics of interest to the staff member conducting this class are presented for advanced study. *Prerequisite: Approval of Department faculty.*

MIM 3915 Special Topics (4QH)
Any Quarter
Topics of interest to the staff member conducting this class are presented for advanced study. *Prerequisite: Permission of Department faculty.*

MIM 3925 Thesis (Master of Science Degree) (2QH)
Any Quarter
Analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. First-year students must attend a graduate seminar program which will introduce the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Successful completion of the seminar program is required. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3930 Thesis (Master of Science Degree) (4QH)
Any Quarter
Analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. First-year students must attend a graduate seminar program which will introduce the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Successful completion of the seminar program is required. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3935 Thesis (Master of Science Degree) (8QH)
Any Quarter
Analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. First-year students must attend a graduate seminar program which will introduce the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Successful completion of the seminar program is required. *Prerequisite: Admission to the Graduate School of Engineering.*

MIM 3940 Master's Degree Continuation (0QH)
Any Quarter

MIM 3945 Master's Degree Project (4QH)
Prerequisite: Approval of adviser.

MIM 3980 Doctoral Reading (2QH)
Any Quarter
Material approved by the candidate's adviser (only S or F grades will be assigned for this course). *Prerequisite: Passing of PhD Qualifying Exam.*

MIM 3985 Dissertation (PhD) Degree (0QH)
Any Quarter

MIM 3990 PhD Continuation (0QH)
Any Quarter

Telecommunication Systems Management

The Master of Science in Telecommunication Systems Management Program at Northeastern University is designed for professionals currently in the telecommunications field who either wish to enhance their technical skills and credentials, or who wish to make a transition to the business side of telecommunications, especially to management or marketing. The disciplines from which students enter include engineering, computer science, the physical sciences, and mathematics. This program is one of only a very few master's programs in telecommunications in the United States that is truly multi-disciplinary. The degree of Master of Science in Telecommunication Systems Management is offered jointly by the Graduate Schools of Engineering and Computer Science, in conjunction with the College of Business Administration.

MASTER OF SCIENCE IN TELECOMMUNICATION SYSTEMS MANAGEMENT

A minimum of forty quarter hours must be earned toward completion of the degree. A minimum grade point average of 3.000 is required over all courses applied towards the degree. A maximum of twelve quarter hours of graduate credit from outside Northeastern University may be counted toward the degree. All transfer credits must be approved by petition before course enrollment.

The program may be pursued on a full- or part-time basis. The program requires that a mix of core required courses and elective courses be taken. As the core courses are all independent of each other, the program may be started in any quarter. In addition, a set of prerequisite courses is available to bridge any gap in the technical background.

There are four core courses and three tracks of electives. The core courses, each carrying four quarter hours of credit, are independent, without firm prerequisites. The core courses provide the essential knowledge base required by a graduate of the Master's program in Telecommunication Systems Management. This knowledge base includes an understanding of: (i) the breadth of the field of telecommunications, both wireline and wireless; (ii) data networking protocols and architecture, particularly the Internet; (iii) public policy and economic issues specific to the telecommunications industry; (iv) the underlying physical infrastructure of the network; and an introduction to business management.

At least three elective courses must be taken from one of the following three specified areas of concentration.

1. Telecom Networking
2. Telecom System Development
3. Telecom Business Management

The three areas of concentration span the networking field. The first, Telecom Networking, is focused on network and communications technology; the second, Telecom Systems Development, on the development of software systems and applications; and the third, Telecom Business Management, on engineering management and marketing. All students must take at least one elective from the Telecom Business Management area of concentration, and one elective from either the Telecom Networking or the Telecom System Development areas of concentration. Electives come from an approved list of courses supplied by the Colleges of Engineering, Business Administration, and Computer Science.

Other courses or a Special Topics course may be used as electives with approval. Participants may elect a Master's Project course in place of one of the electives.

The course schedule permits completion of the degree program in less than four years, assuming that three courses are taken per year and no prerequisite courses are needed. The program may be accelerated by taking courses during the summer quarter.

MASTER OF SCIENCE IN TELECOMMUNICATION SYSTEMS MANAGEMENT DEGREE REQUIREMENTS

Course Requirements	Full-time Study	Part-time Study
Required Core Courses	16 QH	16 QH
Required Electives	24 QH	24 QH
Minimum Quarter Hours Required *	**40 QH**	**40 QH**

* Exclusive of any preparatory courses.

Required Core Courses

		Credits
TSM 3100	Fundamentals of Communication Systems	4
TSM 3200	Telecommunications Architecture & Systems	4
TSM 3300	Data Networking	4
TSM 3400	Telecommunications Public Policy and Business Management	4

Telecom Networking Electives

			Credits
	COM 3510	Computer Networks: Theory, Modeling & Analysis	4
Or	ECE 3511	Network Communications & Performance Engineering	4
	COM 3515	Internetworking: Principles, Protocols & Applications	4
Or	ECE 3650	Local Area Networks and Internetworking	4
	COM 3520	Cryptography & Computer Security	4
	COM 3525	Wireless Networks	4
Or	ECE 3656	Mobile and Wireless Networking	4
	COM 3530	Integrated Services Networks: Design and Evaluation	4
	ECE 3351	Digital Communications	4
	ECE 3514	Error Correcting Codes	4
	ECE 3553	Spread Spectrum Communication Systems	4
	ECE 3559	Wireless Communications	4
	ECE 3657	Broadband Communication Networks	4

Telecom System Development Electives

			Credits
	COM 3301	Database Systems	4
Or	COM 3315	Principles of Database Systems	4
Or	MIM 3128	Database Management Systems	4
	COM 3205	Fundamentals of Software Engineering	4
Or	ECE 3311	Software Engineering 1	4
Or	MIM 3124	Software Engineering	4
	COM 3220	Software Testing, Verification & Validation	4
	COM 3240	Component Based Programming	4
	ECE 3480	Distributed Systems	4
	MIM 3115	Introduction to Software Engineering & Computer Technology	4
	MIM 3140	Concepts of Object Oriented Design	4
	MIM 3141	Component Software Development	4
Or	MIM 3143	Enterprise Software Development	4

Telecom Business Management Electives

			Credits
	ACC 3821	Managerial Accounting	3
	FIN 3860	Financial Management	6
Or	MIM 3207	Financial Management for Engineers	4
	HRM 3914	Managing Professionals	3
	HRM 3860	Organizational Behavior	6
	MGT 3917	Managerial Communication	3
	MGT 3963	Project Management Planning and Implementation	3
Or	MIM 3217	Engineering Project Management	4
	MIM 3102	Planning & Managing Information Systems Development	4
	MIM 3215	Engineering Economy	4
	MKT 3860	Marketing Management	6
	MKT 3918	Marketing and Technological Innovations	3
	MKT 3934	New Product Development	3
	MSC 3824	Managing Information Resources	3
	MSC 3862	Operations Management	6

FACULTY

Dr. Peter O'Reilly, Program Director and Academic Adviser

Full-Time Faculty Associated with the Program

Balachandra, Ramaiya, Professor, College of Business Administration
Chan, Agnes, Professor, College of Computer Science
McDonald, Bruce, Assistant Professor, Electrical and Computer Engineering Department, College of Engineering
Noubir, Guevara, Assistant Professor, College of Computer Science
Salehi, Masoud, Associate Professor, Electrical and Computer Engineering Department, College of Engineering
Tsaoussidis, Vassilis, Assistant Professor, College of Computer Science
Zack, Michael H., Associate Professor, College of Business Administration

Each course description includes information on the expected quarter in which classes are usually offered. The quarters listed are presented here for planning purposes; however, the Graduate School of Engineering cannot guarantee that all courses will be offered. Students must refer to the Graduate School of Engineering Quarterly Course Offering booklets to determine the courses that are actually offered in any given quarter.

TSM 3100 Fundamentals of Communication Systems (4QH)

This course provides a comprehensive understanding of the underlying physical layer technologies used in the telecommunications industry. Topics to be covered include: Signals – types, characteristics (voice, video), spectral analysis. Speech & video compression, sampling, codecs, framing. Transmission principles – concept of a channel, noise, SNR, Shannon's Law, Nyquist limit, crosstalk, echo. Analog & digital modulation. Digital carrier. Introduction to error correction & detection codes. Channel characteristics – twisted pair, coax, terrestrial radio, satellite. Line coding, synchronization, relationship between BER, SNR and link length, power budgets. Multiplexing – FDM, TDM, WDM, DWDM. Echo cancellation, digital speech interpolation. Photonic communications – overview of optics, fiber, sources, couplers, amplifiers. Radio transmission – propagation, multipath fading, antennas, spectrum issues. Cellular systems, handoff. Microwave & satellite transmissions.

TSM 3200 Telecommunications Architecture & Systems (4QH)

This course provides a comprehensive understanding of the telecommunications network today, focusing primarily on the architecture of the network, network systems and overlays of this network. The evolution of the network to packet technologies will be addressed. Topics to be covered include: PSTN architecture – facilities network, access plant. Call processing. Wireline access – ISDN, xDSL & cable modems, fixed wireless. Transmission technologies – FDM and TDM hierarchies, SONET/SDH. Network synchronization. Switching technologies – evolution from crossbar to packet and optical, facility switching. Signaling – in/out-of-band, DTMF, SS7/CCS, architectures, protocols, ISUP, TCAP. Operations – network & service management, network & service provisioning, billing. Vertical services – switch based & directory, Intelligent Networks, AIN call model, local number portability, service creation. Cellular/PCS networks – mobility management, signaling, roaming; overview of analog, TDMA, CDMA, GSM, 3rd generation. Private networks – overlays, PBXs, VPNs. Traffic engineering. Numbering. Routing. Charging. Network migration – voice-over-packet, gateways, softswitches. Standards & industry requirements.

TSM 3300 Data Networking (4QH)

This course provides the basics of data networking protocols and architectures in a relatively non-quantitative manner. Topics to be covered include: Layered architectures – the Internet, OSI model. Local & wide area networks, network topologies. Transport protocols – TCP, UDP, RTP. Data link protocols – encoding, framing, PPP, error control. Statistical multiplexing, queuing, Little's Law. Medium access protocols – Ethernet, token ring, FDDI, 802.11. Packet switching – datagrams, virtual circuits, bridges, ATM switching. Internetworking – inter-domain & intra-domain routing algorithms, naming & addressing, IPv6. Application protocols – ftp, http. Congestion & flow control in the Internet and ATM networks. QoS issues. Network security – cryptography protocols, protocols for security services, firewalls. Network management protocols.

TSM 3400 Telecommunications Public Policy and Business Management (4QH)

This course introduces the student to business management issues such as basic accounting, finance, marketing and operations in the telecommunications field, and also topics such as the time value of money and decision-making. The course also includes issues of human relations, organizational behavior and business strategy. An understanding of the regulatory environment of the telecommunications industry will also be provided. Topics to be covered include: Universal service; service quality tariffs; the Modified Final Judgment and Telecom Act of 1996; market restrictions and segmentation; the current competitive environment in the US and internationally; interconnection – unbundling, collocation, economic issues; global trends in market reform.

University Facilities and Resources

The Boston Campus

The central Boston campus is built around a quadrangle, one side of which faces Huntington Avenue, a major artery dividing the campus. The buildings surrounding the quadrangle and the innovative design of new buildings such as the library and the Egan Research Center that have been added in recent years have maintained an architectural theme that is both attractive and functional.

The campus itself has been planned to provide easy access to classrooms, laboratories, and administrative offices through a series of connected walkways and a network of underground corridors providing routes that are especially convenient during periods of inclement weather. As the University continues to expand, recreational areas are integrated into the campus along with new academic facilities.

Suburban Facilities

Northeastern University's five suburban campuses provide administrative and classroom facilities for the University's graduate, adult and continuing education programs as well as the environment necessary for specific programs of study that could not be accommodated in an urban area.

The Warren Center provides a practical laboratory in outdoor education and conservation, and in camping administration, programming, and counseling. It also offers a summer campsite for various community and University groups and activities and is available as a conference and workshop site.

The Marine Science and Maritime Studies Center is located in Nahant, on Massachusetts Bay, twenty miles northeast of Boston and serves as a site for national and international, as well as University research.

Henderson House is Northeastern University's conference center. Located twelve miles from Boston in suburban Weston, Henderson House hosts a variety of round-the-clock activities including residential seminars, workshops, short courses, and weekend meetings.

The Suburban Campus of Northeastern University is located in Burlington near the junction of Routes 128 and 3. Graduate courses in engineering and business administration, as well as undergraduate courses for part-time students are offered here. The Burlington Campus also offers special programs for adults and noncredit continuing education courses.

The twenty-acre Dedham Campus is located just off Route 128. This facility provides space for the College of Business Administration's High Technology MBA program and offices for the Center for Continuing Education, and houses the University's outdoor track and field facility.

The Henderson Boathouse

The Henderson Boathouse is located on the banks of the scenic Charles River in Brighton, Massachusetts. The five-bay, two-story facility houses both the men's and women's crew teams.

University Libraries

Through their collections, services, staff, and facilities, the Northeastern University Libraries provide access to information integral to all academic and research activities. Librarians assist individuals and groups with bibliographic research strategies and with identifying, locating, evaluating, and using discipline-specific print, non-print, and electronic information resources. The Library offers a comprehensive instruction program, ranging from introductory sessions to advanced electronic database research geared to a particular topic or course. Students may also meet with a librarian to discuss specific or specialized research needs.

Snell Library, a large and comfortable, centralized library on the Boston campus, is open for research and study more than a hundred hours each week that classes are in session. A library at the Burlington campus supports the courses taught there. The collection at the Marine Science Center supports its research activities. Users of the Boston library can request the loan of materials from the Burlington collection, and vice versa.

The total holdings of the University Libraries include more than 936,516 volumes; 2,194,794 microforms; 7,845 serials subscriptions; 163,407 government documents; 20,860 audio, video, and software items; and more than 10,500 licensed-access digital information sources (including e-journals). The collections also include materials such as technical reports, music scores, maps, CD-ROM and other electronic databases, and multi-media resources. Web resources of particular interest to graduate engineering students are *Engineering Information (Ei) Village* (which includes *CompendexWeb*), the full text of the journals of the *Institute of Physics*, the *American Institute of Physics*, and *MathSciNet*. Snell Library is also a selective depository for government publications, an archival depository for University publications, dissertations, and papers, and a repository for special collections.

Library services incorporate advanced technologies associated with information resources and networks, including an online catalog and circulation system, microcomputer and language laboratories, specialized equipment for users with disabilities, a media center with satellite program and remote audio and video transmission capability, a CD-ROM network, and connectivity to NUnet and the Internet. Students can access NULIS (Northeastern University Libraries Information System) from outside the Library via NUnet or through dial-in.

Many other library services are available to students, including a student peer tutoring program. There is an extensive language facility for students who wish to improve their speaking skills in English, or who wish to develop their skills in another language in preparation for working abroad. Students who wish to design and create quality visual presentation materials for class or for other talks, papers, and posters, may use the photographic, graphic, and computer facilities of the Media Production Laboratory. View the Library's Web site at **www.lib.neu.edu** for additional information about collections, services, and hours.

Other libraries and collections on the Boston campus include the African-American Institute Library, the Career Development and Placement Library, the Hillel House Collection, and the Law Library; these are administered separately from the University Libraries system.

Northeastern University is a member of the Boston Library Consortium, a cooperative arrangement among sixteen major academic and research institutions. Students may apply for a card that grants borrowing privileges at consortium libraries.

Information Services Customer Services (ISCS)

As the front door to the entire Information Services organization, Customer Services (ISCS) is comprised of the newly expanded InfoCommons (Computer Help Desk, Training Services, and Computer Labs), the Call Center/Computer Help Line, ResNet, and other Computer Labs. For information about appropriate use of University computing facilities, and how to access our services, please contact us via the ISCS Web site: www.help.neu.edu, or by telephone at 617.373.3300.

Graduate Student Housing

Housing in a University apartment facility is available on a first-come, first-served basis. These fully furnished apartment facilities offer units designed for one, two, three, or four students. For more information about graduate student housing, call 617.373.2814 or view their Web site at **www.northeastern.edu/housing/gradlaw/styles.html**.

Department of Career Services

The Department of Career Services offers career counseling and job search assistance to all Northeastern students and alumni/ae. Career counseling helps our clients make decisions about a college major or career direction, develop plans for a career change, create effective job search strategies, or explore any other career related issue. Job search assistance is available through resume matching, a computerized system that matches the candidates resume with professional positions listed by employers. The On-campus Recruiting program brings representatives from more than two hundred employer organizations to Northeastern to interview graduating students for full-time employment.

The Career Resource Center houses a collection of career literature, including occupational information, resume and interviewing resources, job search guides and directories of employers. The Center maintains a job bank of current local, national, and international job opportunities and internships. Employer files contain annual reports, product information and descriptions of training programs. Daily walk-in hours allow students and alumni/ae to seek convenient assistance with resumes, job search correspondence or any other career related questions.

Sport, Dance and Exercise Facilities

Through its Cabot Physical Education Center, the Marino Center for Physical Education, Dockser Hall, and the Barletta Natatorium, Northeastern University offers a wide variety of specialized facilities, including basketball courts, dance studio, indoor athletic field and running track, gymnastics room, combatives room, weight-training rooms, swimming pool, crew practice tank, racquetball courts, and motor performance and exercise physiology laboratories. Matthews Arena, with seating for more than 5,000 fans, provides home ice to the University's varsity and intramural hockey teams and, when the portable playing floor is down on the ice, home court to the University's basketball teams.

For organized athletics requiring facilities not available on the main campus, Northeastern maintains several off-campus locations, including the Henderson Boat House, in Brighton. The Edward S. Parsons Field, on Kent Street in Brookline, is the playing ground for the football, baseball, women's lacrosse and women's field hockey teams, tennis, and some intramurals.

The Bernard and Jolane Solomon Track

The Bernard M. and Jolane Solomon Track, an outdoor track and field facility in Dedham, has an eight lane. Action Track 200 running surface, and an expansive area for con-current jumping and field events. This facility hosts dual and championship meet competition, and is a permanent site for Northeastern University track athletics.

Curry Student Center

The Curry Student Center is home to Northeastern's 140 Student Organizations, Student Government Offices, Information Center, Copy Center, The Print Media (The Northeastern News, Yearbook, etc.), and WRBB Radio Station. In addition, the Center houses a computer lab, meeting rooms, student lounge, the Commuter Services office, and the Ballroom which serves many social and academic functions.

The Curry Student Center is supported by student fees and strives to offer a comfortable atmosphere for commuter and resident students alike. It is also used by the Northeastern community for the many social, recreational, academic, and cultural activities held on campus.

Lane Health Center

A comprehensive program of medical care is provided to all full-time graduate and undergraduate students. The University maintains a Health Services Clinic equipped to deal promptly with any medical condition that may arise. All entering full-time students must submit a pre-entrance physical examination form provided by the Lane Health Center prior to registration. Failure to fulfill this requirement can delay registration and result in a penalty fee and additional fee for a physical examination. For more information, view their Web site **www.dac.neu.edu/lane.health.center**.

Center for Counseling and Student Development

The Counseling and Student Development Center provides a broad range of counseling services for Northeastern students. These services include assistance in resolving personal loss and life adjustment problems, developing satisfying interpersonal relationships, choosing an appropriate college major, career planning, improving study skills, and dealing with difficult feelings such as excessive anxiety or depression. The center provides short-term counseling (up to twelve sessions during an academic year). Assistance is offered in the form of referrals and resources if longer term treatment is needed.

In addition to individual counseling, students may take psychological tests to increase their knowledge of themselves, join a group of students with whom they share concerns, and use self-help tapes. There is no charge for these services for enrolled NU students.

Disability Resource Center

The Disability Resource Center's (DRC) mission is to ensure that students with disabilities have equal access to higher education via support services and advocacy. DRC provides support services on an individual basis. The Center's services include, but are not limited to: readers and scribes, sign-language interpreters and translators, note-taking, disability-related academic advice, liaison and advocacy services for students, faculty, staff, and administrators, counseling and referral services, campus orientation, accessible accommodations, support groups and HP parking.

The DRC offers services to support to people with a range of disabilities, including but not limited to: individuals with mobility impairments, learning disabilities, individuals who are Deaf or hard of hearing, persons with chronic or degenerative disorders, or people with psychological disorders.

For more information please contact the Disability Resource center at 617.373.2675; TTY: 617.373.2730 or view their Web site at **www.access-disability-deaf.neu.edu**.

Network Northeastern (NNU)

Network Northeastern uses the microwave-based Instructional Television Fixed Service (ITFS) system to broadcast courses to subscriber companies and to the Burlington and Dedham campuses. The network telecasts live classroom instruction from the Boston campus to remote sites where students interact with instructors via a telephone-based talkback system. Class materials are delivered via courier service, U.S. mail, facsimile, or electronic mail.

Network Northeastern currently broadcasts graduate courses in electrical engineering, mechanical, industrial and manufacturing engineering and information systems to over thirty local corporations. Network Northeastern also delivers graduate level and short courses to corporations throughout the U.S. via satellite. For more information please contact Network Northeastern at 617.373.5620, mail your request to 328 Columbus Place, Boston, Massachusetts, 02115, or view their Web site **www.neu.edu/network-nu**.

English Language Center

The English Language Center (ELC) provides an important resource for students at Northeastern who speak English as a second language. Its goal is to ensure that students are proficient enough to carry full-time studies in a degree program without language-related problems.

The ELC provides language courses and testing for students who have been conditionally admitted to Northeastern as well as any full-time enrolled student who would like language support.

In addition to serving students, the English Language Center provides advice and consultation to the Northeastern community at large. The Center's staff are available to answer questions from teachers, administrators and students, and are able to design special programs for special needs on short notice. For more information please contact the English Language Center at 617.373.2455, or view their Web site www.neu.edu/elc.

International Student & Scholar Institute (ISSI)

(Formerly the International Student Office)

The International Student and Scholar Institute (ISSI) coordinates an array of services and programs for approximately 2,700 international students and scholars from more than 130 countries. Services to the international community range from advising and interpreting immigration regulations and federal laws, to organizing a host of cultural enrichment programs and diversity educational initiatives. The ISSI also assists with international admissions, cultural adjustment issues, visiting faculty appointments, student leadership development, sponsored international student concerns, and numerous matters that pertain to graduate and undergraduate students in the context of international and intercultural exchange.

In addition, the ISSI administers an Intercultural Library and Resource Area that houses books and other resource materials in a variety of languages. The ISSI strives to foster an appreciation of all cultures and to facilitate cross-cultural understanding, especially between American and international students. To achieve this aim, ISSI staff work closely with student organizations, University departments, and community institutions. The ISSI sponsors more than twelve weeks of international orientation programming throughout the year, as well as a two-month cultural festival (*International Carnevale*), an international spouse network (Common Ground), a cultural lunch series (Beyond Borders), an alumni contact directory/mentoring initiative (Global Connections), an educational seminar series/induction (Phi Beta Delta Honor Society for International Scholars), informal discussion groups with a cross-cultural focus (Conversation Peace), and regional excursions as part of its "ISSI on the Go" series.

The ISSI is comprised of the following service units: International Student Services and Intercultural Programs, International Scholar Services, and the Intercultural Library and Resource Area. Visit the International Student & Scholar Institute, Northeastern University, 206 Ell Hall, Boston, Massachusetts, 02115 for further information, or call the ISSI at 617.373.2310, or view their web site at **www.issi.neu.edu**.

Additional Information about Northeastern University

The Northeastern University Graduate School of Engineering Student Guide and Catalog contains the University's primary statements about graduate engineering academic programs and degree requirements, as authorized by the President or Board of Trustees. For information about other academic policies and procedures; student responsibilities; student academic and cocurricular life; faculty rights and responsibilities; or general personnel policies, benefits, and services, please refer to the *Academic Operations Manual, Undergraduate and Graduate Student Handbook, Cooperative Education Handbook, Faculty Handbook, Benefits and Services Handbook*, or related procedural guides, as appropriate.

Accreditation Statement

Northeastern University is accredited by the New England Association of Schools and Colleges, Inc., which accredits schools and colleges in the six New England states. Accreditation by the association indicates that the institution has been carefully evaluated and found to meet standards agreed upon by qualified educators.

Delivery of Services

Northeastern University assumes no liability for delay or failure to provide educational or other services or facilities due to causes beyond its reasonable control. Causes include, without limitation, power failure, fire, strikes by University employees or others, damage by natural elements, and acts of public authorities. The University will, however, exert reasonable efforts, when it judges them to be appropriate, to provide comparable services, facilities, or performance, but its inability or failure to do so shall not subject the University to liability.

Emergency Closing of the University

Northeastern University has made arrangements to notify students, faculty, and staff by radio and television when it becomes necessary to cancel classes because of extremely inclement weather. AM stations WBZ (1030) and WRKO (680), and FM stations WBUR (90.9) and WFNX (101.7) are the radio stations authorized to announce the University's decision to close. Television stations WBZ-TV4, WCVB-TV5, WHDH-TV7, and WLVI-TV56 also report cancellations. Since instructional television courses originate from live or broadcast facilities at the University, neither the classes nor the courier service operates when the University is closed. Please listen to the radio or television to determine whether the University will be closed. If a storm occurs at night, the announcement of University closing is given to the stations at approximately 6 AM. Classes are generally canceled for that entire day and evening at all campus locations unless stated otherwise. When a storm begins late

in the day, cancellations of evening classes may be announced. This announcement is usually made between 2 PM and 3 PM.

Equal Opportunity Policy

Northeastern University is committed to providing equal opportunity to its students and employees and to eliminating discrimination when it occurs. Northeastern University does not discriminate on the basis of race, color, religion, religious creed, sex, sexual orientation, age, national origin, ancestry, veteran or disability status. Moreover, the University will not ignore any form of discrimination or harassment including sexual harassment. Nor will Northeastern condone any form of retaliatory activity against any person who brings a complaint of discrimination or harassment or who cooperates in a complaint investigation. Handbooks containing the University's nondiscrimination policies and its grievances procedures are available in the Office of Affirmative Action and Diversity, Columbus Place, Room 424. Inquires regarding the University's nondiscrimination policies may be directed to:

Donnie Perkins, Dean/Director
Office of Affirmative Action and Diversity
716 Columbus Place, 4th Floor/Room 424CP
Northeastern University
Boston, MA 02115
Phone (617) 373-2133
TTY (617) 373-5814
Fax (617) 373-4146
Email: d.perkins@neu.edu

Inquiries concerning the application of nondiscrimination policies may also be referred to the following organizations. The Regional Director, Office for Civil Rights, United States Department of Education, J. W. McCormack Building, Post Office Court House, Room 222; Boston, Massachusetts 02109-4557. Massachusetts Commission Against Discrimination (MCAD), One Ashburton Place; Boston, Massachusetts 02108-1518. Equal Opportunity Commission, One Congress Street, 10th Floor, Room 1001; Boston, Massachusetts 02114.

Family Educational Rights and Privacy Act

In accordance with the Family Educational Rights and Privacy Act of 1974, Northeastern University permits its students to inspect their records wherever appropriate and to challenge specific parts of them when they feel it is necessary to do so. Specific details of the law as it applies to the University are printed in the *Undergraduate and Graduate Student Handbook* and are distributed annually at registration for the University's colleges and graduate schools.

Insufficient Enrollment Disclaimer

Northeastern University reserves the right to cancel any course if minimum enrollments, appropriate faculty, or academic facilities are unavailable to meet standards.

Tuition and Fee Policy

Tuition rates, all fees, rules and regulations, and courses and course content are subject to revision by the President and the Board of Trustees at any time.

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[1] Also College of Engineering Graduate Affairs Committee members.
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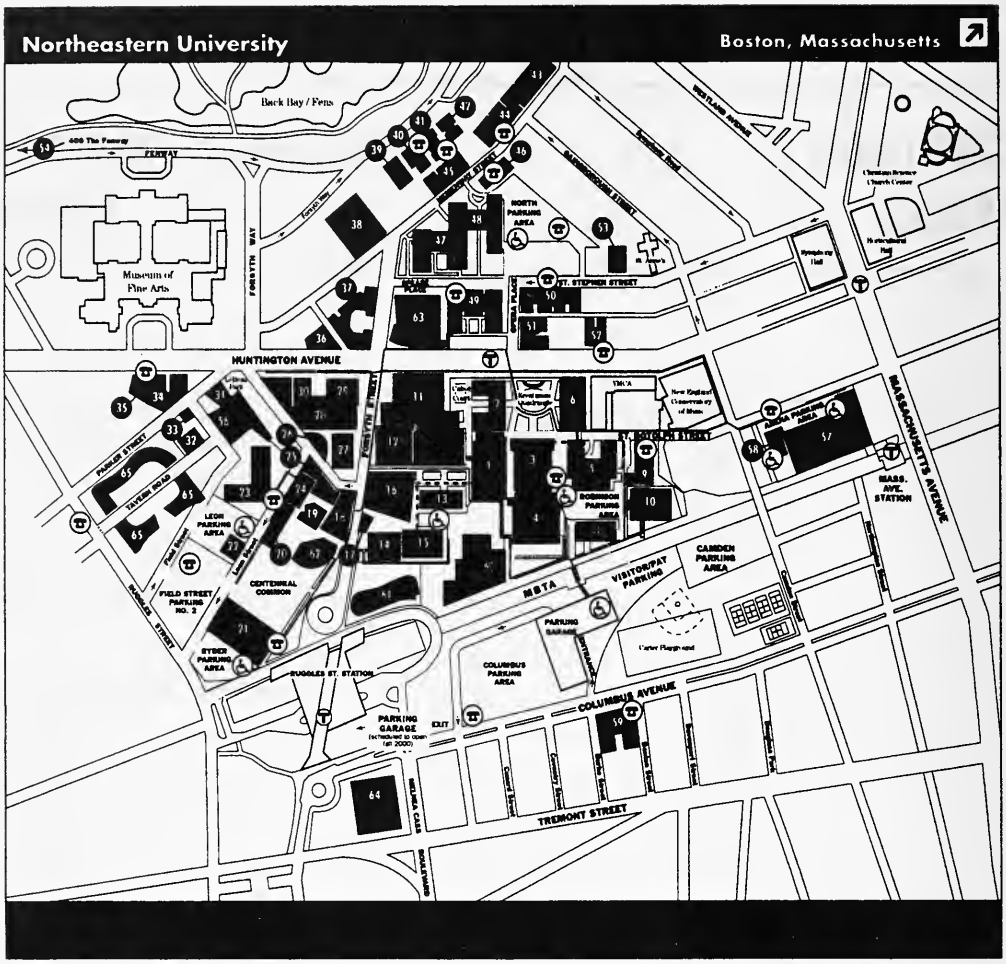
Campus Maps



Academic and Service Buildings

- 22 John D. O'Bryant African-American Institute (AF)
- 12 Barletta Natatorium (BN)
- 19 Boiler Plant
- 11 Cabot Physical Education Building (CB) TTY: Rm 110
- 39 Cabners Hall (CA) TTY: Rm 151
- 28 Cargill Hall (CG)
- 13 Churchill Hall (CH)
- 59 Columbus Place (716 Columbus Avenue) (CP)
- 9 Cullinane Hall (CN)
- 4 John A. and Marcia E. Curry Student Center (Student Lounge) (SC) TTY: Rm 255
- 40 Cushing Hall (CU)
- 14 Dana Research Center (DA)
- 27 Dockser Hall (DK) TTY: Rm 107
- 6 Dodge Hall (DG)
- 61 Maureen and Richard J. Egan Engineering/Science Research Center
- 3 Ell Student Building (Auditorium) (EL) TTY: Rms 04, 104
- 56 Field Street (FS)
- 16 Forsyth Building (FR) TTY: Rms 100, 135
- 17 Forsyth Building Annex (FA)
- 38 Forsyth Dental Building (FE)
- 1 Hayden Hall (HA) TTY: Rms 120, 202
- 33 Hillel-Frager (HF)
- 24 Holmes Hall (HO) TTY: Rm 276
- 10 Hurtig Hall (HT)
- 26 Kariotis Hall (KA)
- 41 Kerr Hall (Faculty Center) (KH)
- 29 Knowles Center (KN)
- 25 Lake Hall (LA) TTY: Rm 203
- 63 Roger M. and Michelle S. Marino Recreation Center (MC)
- 57 Matthews Arena (MA)
- 58 Matthews Arena Annex (MX)
- 20 Meserve Hall (ME) TTY: Rm 305
- 5 Mugar Life Science Building (Peabody Health Professions Center) (MU)
- 18 Nightingale Hall (NI) TTY: Rm 125
- 31 Parker Building (PA)
- 64 Renaissance Park (RN)
- 2 Richards Hall (RI) TTY: Rms 150, 254
- 8 Robinson Hall (RB)
- 21 Ryder Hall (RY) TTY: Rms 170, 180, 251, 270
- 50 122 St. Stephen Street (SS)
- 62 Shillman Hall (SH)
- 15 Snell Engineering Center (SN) TTY: Rm 120
- 60 Snell Library (SL) TTY: Reference Desk
- 30 Stearns Center (ST) TTY: Rm 302
- 32 26 Tavern Road (TA)

Residence Buildings

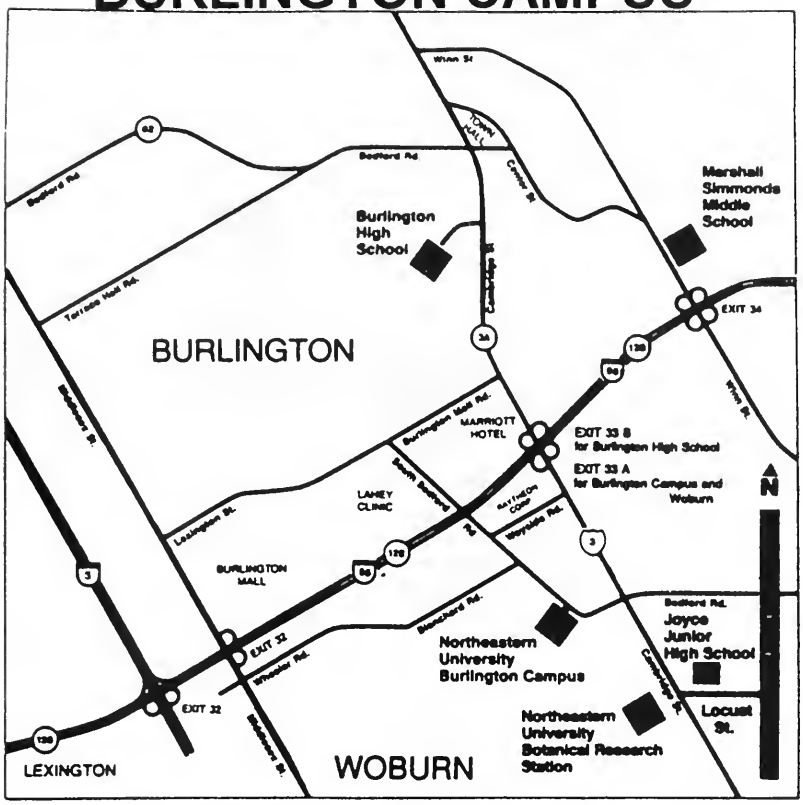
- 34 Burstein Hall
- 54 400 The Fenway
- 46 142–148 Hemenway Street
- 45 153 Hemenway Street and Loftman Hall
- 7 316 Huntington Avenue (Northeastern at the YMCA)
- 52 319 Huntington Avenue
- 51 337 Huntington Avenue
- 36 407 Huntington Avenue
- 43 Kennedy Hall
- 41 Kerr Hall
- 53 Light Hall
- 45 Loftman Hall and 153 Hemenway Street
- 42 Melvin Hall
- 35 Rubenstein Hall
- 50 106/110/116/122 St. Stephen Street
- 44 Smith Hall
- 49 Speare Hall
- 48 Stetson East TTY (public)
- 47 Stetson West
- 65 West Village Residence Complex (Halls B and C scheduled to open fall 2000)
- 37 White Hall
- 23 Willis Hall

Key

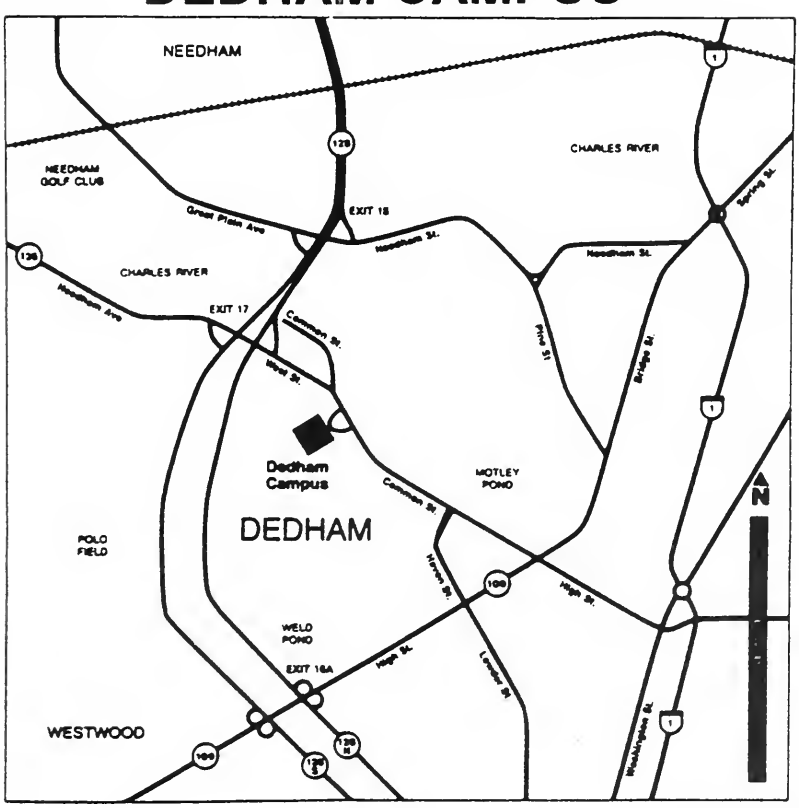
- Academic, residential, and service buildings
- Handicap parking
- Accessible routes
- Parking areas
- Street direction
- Underground tunnel
- Emergency telephone
- TTY locations — See alphabetic list of buildings for TTY locations. (TTY: Rm 000)

Maps are provided by the Information Center, 115 Richards Hall, extension 2736 (TTY extension 3768). Some buildings on this map are used but not owned by Northeastern University. 2/00

BURLINGTON CAMPUS



DEDHAM CAMPUS



INDEX

Graduate School of Engineering
130 Snell Engineering Center
Northeastern University
360 Huntington Avenue
Boston, MA 02115
617.373.2711 (voice)
617.373.2501 (fax)
grad-eng@coe.neu.edu
AOL Keyword: Northeastern University

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